HUDAC

Effect of High Levels of Insulation on the Heating Fuel Consumption of Canadian Houses

A REPORT BY

SCANADA CONSULTANTS LIMITED

FOR THE

HUDAC TECHNICAL RESEARCH COMMITTEE

Housing & Urban Development Association of Canada

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ACKNOWLEDGEMENTS

Appreciation must be expressed to the householders in Winnipeg, Toronto and Ottawa who patiently answered all the questions and suffered the intrusion of strange engineers peering into attics and furnaces.... and to the builders, Ensign in Winnipeg, McClintock in Scarborough, Costain in Toronto and Minto in Ottawa, for building and selling such highly insulated houses in the first place and for providing descriptions, locations and liaisons required to allow this study.... and to Ontario Hydro, Consumers Gas and Ottawa Gas for assistance in obtaining the energy and fuel consumption records for all houses.

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EFFECT OF HIGH LEVELS OF INSULATION ON THE HEATING FUEL CONSUMPTION OF CANADIAN HOUSES

SUMMARY

Do higher levels of insulation perform as well as theoretically expected in reducing house heating fuel consumption? Do the higher insulation levels themselves cause further operational or durability problems? This field survey was designed to answer those two questions. The actual heating fuel consumption (or electrical heating consumption, for a minority of the cases) has been analyzed for recent winters for sixty-seven occupied houses grouped together in three cities, Toronto, Ottawa and Winnipeg, encompassing Canadian winter climates from moderate to severe. The houses range in type from small row units to large singles and in level of insulation from moderate to very high in present Canadian terms, ie. from R 2 (11) walls and R 2.1 (12) attics up to R 3.5 (20) walls and R 7.2 (41) attics (R's are in SI units; Imperial R in brackets).

While the houses are generally similar (and built by one builder) within each city, the range of units surveyed is adequately wide to answer the primary questions above. (Theoretically the heating consumption in one given winter for these houses should range from very low for the smallest highly-insulated (HI) unit to about four times higher for the largest less-highly-insulated (LHI) house.) Further, the survey design included direct comparisons of insulation effect between paired houses in the groups, each pair comprised of an LHI and an HI generally similar in all but insulation level (6 pairs in each city, or 36 out of the 67 houses). The field survey included testing of furnace

efficiency, overall airtightness, indoor temperatures and relative humidity, insulation placement (thermography samplings), and inspections for problem telltales, appliance counts, and questionning of householders on living habits, conserving attitudes and problems.

On the whole the results are conclusive, and the conclusions are:

1) Higher levels of insulation do reduce heating fuel consumption commensurately; the savings follow theory; high levels of insulation work in houses about as well as in the laboratory.

2) A high level of insulation in new houses (eg. R 3.5 and higher), as compared to moderate levels (eg. R 2.1), does not change overall air leakage characteristics or relative humidity (RH) and does not cause problems with the exception that signs suggestive of truss lifting do appear to be associated with high levels only (R 5.6 and higher, in this field survey).

3) A high level of insulation in new houses does not yield more uniform temperature, RH, or better "comfort" than does a moderate (1975 standard) level.

4) Living habits and seasonal furnace efficiency taken together (this field study generally could not separate their effects) do play a strong part in heating consumption, particularly so in the milder city, Toronto (probably due to "looser" habits and intermittent furnace cycling where the winter months are less steadily cold).

5) The lowering of indoor temperature is one living habit that appears to reduce heating bills sharply.

EFFECT OF HIGH LEVELS OF INSULATION ON THE HEATING FUEL CONSUMPTION OF CANADIAN HOUSES

INTENT AND SCOPE

House builders and buyers may fear that the energy conserving effects of greatly increased standards of insulation are not known and may prove partly nullified in the realities of running a house. Somewhat conversely, fears are expressed that the efficacy of high levels of insulation may result in increased airtightness entailing problems in control of humidity, odour and condensation. The question is a basic one: are the increasingly greater investments in higher standards of insulation for new housing fully justified by commensurate savings in fuel bills? Put another way, are the savings as great as predicted by heat demand theory, the theory that underlies the imposition and degree of higher standards? The intent of the field work here reported is to answer these questions.

The field work draws upon the fact that, since one or two years ago, some builders have introduced very high* insulation levels as market attractions. Their houses are running as "test vehicles" in advance of the imposition of such high standards. In some cases they are built contiguously with the builder's preceding models which are similar in all or most respects (size, shape, orientation, windows, furnaces and sometimes occupancy) excepting the degree of insulation.

* Insulated well above current code requirements

The intended approach of this study was to find and pair such cases of highly insulated houses against distinctly less insulated counterparts, ie. "highly-insulated vs. moderately-insulated" pairings to determine clear-cut performance differences. However, many of the existing "twins" that have been located (meeting the criteria of equality in all but degree of insulation) are not sharply different in insulation. The builders now offering very high levels had already been building to levels above the code, in most regions. In these cases the performance comparisons become less sharply differentiated, a matter of highly-insulated houses against less-highly-insulated counterparts.

Hence the final study has been designed perforce around the available resources to encompass a very wide overall range of theoretical heat loss coefficients (G)*, as well as some wide differential in insulation and also a broad range of climatic severities. This was done by including shared-wall row house units in Ottawa for extremely low G's, Winnipeg houses of moderate size in a cold climate, and large Toronto houses for higher G's with well-differentiated insulation levels. Since the theoretical whole-house heat loss coefficient G is derived directly from laboratory resistance ratings of the insulation, and since the field groupings are chosen to give similar orientation, exposure and "free heat" aspects among the groups, it follows that <u>the proof of the validity of theoretically highly-conserving house envelope practice will be revealed simply by good correlation between actual heating consumption and the house G's even into a very low range of G's.</u>

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*G = conduction heat loss estimated from building plans + infiltration heat loss estimated from measured airtightness

... per degree hour (Appendix 5)

METHOD

Thirty-six houses were selected to comprise eighteen pairs, each pair featuring one highly insulated (HI) case and one less-highly insulated (LHI) case similar in other respects, ie. floor area, volume, window area and orientation. Six pairs are Ensign houses in Winnipeg, six are McClintock's in Toronto and six are Minto's in Ottawa. Tables 1, 2 and 8 list their characteristics and Fig. 1 presents photos of all. These are the "core cases", the fully paired cases, all subjected to field inspections and analyses and favoured by full cooperation of householders.

In addition a further twenty-seven* such units were obtained as unpaired "extra" check cases, same models, same neighborhoods, to broaden the sampling for better statistical soundness for each locality. Efforts were made continually to find more but no further suitably similar units were found with accessible fuel records. Costain added fuel consumption results for seven Toronto houses, three houses of high insulation levels in special wall constructions and attics, vs. three less-highly insulated counterparts, and a fourth HI with no counterpart LHI fuel record. Although paired, these Costain houses are used as extra cases only, since the houses have not been subjected here to field inspections. The total number of houses assessed in this heating performance study is sixty-seven.

Procedure:

1) The householder completed a questionnaire concerning any additional insulation or other conserving changes to the house since construction; also energy-related occupancy facts, living habits (Appendix 1).

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* three discarded (incomplete fuel records).

2) Engineers visited each house to review the questionnaire with the householder and test the furnace's efficiency (Appendix 2), overall airtightness (Appendix 3) and temperatures and relative humidities (accurately) in most rooms. Interiors were checked visually for leaks, cracks, dust marking, condensation, truss lifting and amount of insulation (basements, upper walls, ceiling, windows, doors, attics). (Appendix 4).

3) In each city four houses (two HI's and two LHI's), twelve in all, were examined by infrared thermography to check insulation and air leakage patterns (special report).

4) Using the above steps and all measured dimensions and "laboratory" thermal resistances, the theoretical G's were calculated for each house (Appendix 5), allowing individually for air change rates as inferred by the airtightness test results (Ontario Hydro general correlation of one to the other, Appendix 3).

5) Fuel and electrical consumption records were obtained from the utilities or householders for the preceding two years or, in some newer Winnipeg and Ottawa cases, for the preceding year and the winter now ending. (This latter necessity delayed the completion of the study until the end of April).

6) Energy consumed for domestic hot water heating was calculated (Appendix 6) and subtracted from the foregoing; for the several electrically heated houses an additional netting was required: the removal of the portion of energy consumed by lighting and appliances (Appendix 7). The remainder of the recorded energy consumption is gross energy into space heating. ("Gross": the fuel energy <u>into</u> the

furnace, not the net energy usefully replacing house heat losses. To allow the several electrically heated house figures to be used as case points comparable to the great number of gas-heated cases, a fixed multiplier of 1.38 was applied to "convert" them to gross space heating as if gas heated. This assumes a single seasonal efficiency of 0.9 for the electric warm air furnaces and 0.65 for the gas warm air furnaces).

7) Normalization of all space heating energy figures to represent one single heating season was done simply by dividing each by the particular number of degree days elapsed in the one or two heating seasons for which the energy consumption was recorded.

8) The gross heating energies were then plotted against the house G values and all inferences are taken directly therefrom with no adjustments or discarding of points. The measured values of furnace efficiency and room temperatures and the reported occupancy loads and habits may be used for commentary only. The assumption here is that the 67 cases are sufficiently numerous that all attributes of houses and people scatter blindly insofar as G is concerned. (The exception is seasonal efficiency of furnace, deemed impossible to calculate here, which will bias the heating performance <u>against</u> the better insulated houses (lower G) since the furnaces are more grossly oversized for these. However only the Toronto houses have a substantial difference between HI's and LHI's; and most of the HI's are electrically heated.

9) The householder responses were then tabulated and assessed regarding comfort, problems, buying motivation, energy-saving attitudes and the like, again to check for possible bias favouring HI's or LHI's.

RESULTS AND DISCUSSION

The house envelope and heating consumption

Fig. 2 presents the space heating findings for the sixty seven houses, against their theoretical envelope loss coefficients "G". Energy consumption is placed in effect on a common heating season basis to remove the effect of locality (as noted under Method), so that G alone should be reflected. That is, energy consumption is plotted against the function of theoretical thermal resistance and the house size (envelope area) plus the smaller air change component also dependent in large part upon the envelope. The scatter of results is large but not as much as expected. (The removing of hot water energy and the deducing of air change are each very imprecise operations involving large amounts, but all is done consistently and "blindly" to G). The pattern of results is clear, the correlation factor being 0.88: fuel bills do depend directly on envelope quality and size even at very high thermal quality and over a wide range of climate severity. Comments are added to the figure where observations taken may account for some of the scatter.

Fig 3 follows the original intent, presenting the core series of pairs in a manner largely eliminating the effect of house size and locality and hence expressing, on the whole, only the relationship between insulation level and the fuel bill. This one-on-one approach invites wide scatter of results particularly since the Ottawa units and some of those in Winnipeg differ little in overall insulation level. If say the heating behaviour of an HI were a little off while that of its LHI counterpart were just slightly better than normal, then that pair will infer sharply that added insulation has caused substantially increased fuel bills. The scatter does drift that far but clearly that is an anomaly: on average, and with surprisingly few exceptions, the direct pairing shows that the fuel bill remains dependent on insulation level even into these high levels. (The "slightly off" showing of the Toronto HI's vs. LHI's may be due to the unfortunately unavoidable pairing of electric furnace HI's with gas heated LHI's. The arbitrary fixing of one efficiency multiplier to render the former directly comparable to the gas heated LHI's renders the Toronto comparison somewhat unsure. Also, two "pairs", one in Ottawa and one in Winnipeg, had to be dropped from Fig. 3 because they proved ill-paired, ie. the LHI owners had generally changed the houses to such an extent that their G's equalized with the HI G's, the G change not reflecting insulation level alone. Their inclusion would not affect the overall results. All cases including the extras are usable in the earlier Fig. 2 comparisons which is the particular strength of that approach.)

Clearly the absolute heat flow through, and the absolute savings due to, the thermal resistance of every square metre of house envelope are facts fixed only by the resistance and the driving force, the temperature difference between indoor and outdoor surfaces -- despite any proportional masking by factors such as furnace efficiency or living habits. Only one living habit, lowering the indoor temperature, can reduce the absolute savings effect of the insulation. Nothing in Figs. 2 or 3 refutes basic physics nor suggests that insulated assemblies perform significantly worse in the field than in the laboratory.

Direct comparison of actual to theoretical heating consumption

Although not a part of this study (primarily because it was not possible to determine seasonal efficiency of furnace) it may be instructive to attempt the direct step of comparing the actual "fuel bill" against the theoretically predicted consumption, where the latter puts full weight on both insulation (R) and degree days. Figure 4 does just that, using the Scanada heating prediction method.* (In this case it was "blind" to the individual house orientation, occupancy, indoor temperature and seasonal efficiency, assuming an "average" value for all. Seasonal efficiency was taken as 60% for gas and 90% for electric furnace.)

The direct comparison of actual against this "average-condition-theoretical" consumption again supports the full value of insulation. Note also that it shows again the better-than-expected performance in the colder region. ("Free Heat" effects are built in to the prediction method from warmer area experience).

If the theoretical prediction method were applied to the houses with calculated allowances for indoor temperature and setbacks, orientation and passive solar effects, occupancy, and furnace seasonal efficiency, very much of the scatter of the points would be removed. Since the seasonal efficiency is not decipherable from the field work such individual modelling can not be done. The partly blind "average condition" plotting does have the advantage of ensuring that no accidental or intentional bias has become part of the strong pattern of Fig. 4.

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* See Appendix 5

Comfort

Householder responses to the questions on home comfort are tabulated in Table 3. The particular responses of "poor" were further investigated and discussed during the visits to each house.

Only one group of houses (Toronto) presents a substantial difference in level of insulation between the high and the lower, and there the responses suggest better comfort in the HI's. However these units have a different heating system (electric furnace, no flue) than that of the LHI's. Further, the Ottawa LHI's are given just as great a superiority in "comfort" over their HI counterparts, whereas in Winnipeg all is closely balanced. Given that all houses are well insulated and present no cold surfaces (other than the windows) to cause radiant chilling, it would be surprising to find a clear revelation on the subjective matter of "comfort" in a shift from good to better insulation.*

Tables 4A and 4B set out the winter indoor temperature and relative humidity readings as measured during the site visits. Temperatures were taken at floor level (15 cm. above the floor) and mid-height, and all measurements were repeated in several rooms. Both the average levels and the uniformity of temperatures and relative humidity reveal no distinction between HI's and LHI's; extra insulation has not affected "comfort" insofar as these characteristics are part of it.

Problems

Householder responses and subsequent field inspections established a picture of scattered problems. No pattern

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*Houses were fully carpeted with the exception of kitchen, bathroom, and unfinished basement floors.

emerged suggesting more or less construction care distinguishing HI's from LHI's. The single problem bias marking the higher insulation usage fairly clearly is truss lifting. The problems:

a) Found in some HI's and LHI's alike in at least one and often two out of three regions (all three contributing to the list):
   - air-leaky sliding windows, doors, patio doors, fireplace dampers and attic hatches (25 cases)
   - infiltration at electrical outlets, some sills (7 cases)
   - nail popping, especially bathroom ceilings (10 cases)
   - appreciable (2 cases) and substantial (2 cases) amounts of attic condensation or ceiling tell-tales of same usually over the attic hatch
   - condensation on interior side of windows (18 cases)

b) Found in one LHI only
   - wall surfaces objectionably cold in one corner (later traced by thermography to corner air leakage facing a severe northern exposure)

c) Found in HI's only
   - two houses, sagging gypsum board ceiling
   - two houses, heavy condensation interior side of windows
   - seven houses, two regions: wall-ceiling joint cracks suggesting some incidence of truss-lifting ('W' trusses)

In addition the thirty-six houses had the normal range of problems not related to the insulated envelope, particularly some basement and sill area leakiness. The potentially troublesome exhibitions of attic condensation were associated with two electrically heated houses only, LHI and HI, and were concentrated over poorly sealed hatches. The complete inspection of all these houses while relatively new establishes a good base for follow-through after more winters to monitor trends and solutions in the newer, more air-tight Canadian housing stock.

Thermography

The thermography sampling verified and clarified all the foregoing points regarding sliding window, door, sill and attic hatch leakage. It revealed that all batts are in place in both LHI's and HI's, that some are not snugged down well in attics, and that interior surface temperatures consistently show the presence of good levels of insulation and the slight improvement with better levels, as expected. Poor heat distribution (probably attended by direct warm-air loss to the outdoors) is revealed where ducts are run against the interior surface of exterior walls even though the walls appear well insulated behind the ducts. The thermography work is being produced as a special separate report.

Air leakage and inferred air change

Table 5 records the Equivalent Leakage Area of the houses as tested under negative pressure, fan exhausting (Appendix 3). Then an inference is drawn on air change, ie. the seasonal average air change rate that appears to correlate with the leakage test results, according to Ontario Hydro's experience in correlating*these not-always-related characteristics. The inferred air change is used as a small part of the theoretical heat loss coeff. "G".

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* The inferred air change rate does seem unrealistically low

The houses appear to be fairly consistent within their groups and are rather airtight, particularly the Winnipeg units (which would appear to court problems by being too airtight, which of course is the better way to err; backing off to "looser" operation is easy). The Ottawa houses appear much looser but these incorporate outdoor air vents which are normally open (no damper) and were tested so. The singular finding by all the testing is that LHI's and HI's are equals: added insulation has not air-tightened the houses.

Buyer attitudes

Table 6 summarizes the responses to selected questions on awareness of energy conservation.

On the site visits, the engineers learned that many people were aware of the insulation levels in their homes. Thus, not surprisingly, most owners of HI's felt their homes were well-insulated and energy efficient while the owners of LHI's were somewhat less satisfied with their present "thermal status". Nevertheless, equal numbers of owners of LHI's and HI's plan to make further energy-saving changes to their houses.

The questionnaire sought to determine how energy-conscious the home-owners are and in particular whether energy-consciousness was related to the purchase of the better insulated house. Closing the fireplace damper when the fireplace was not in use, turning back the thermostat at night, regular servicing of the furnace, controlled opening of exterior doors and windows, the night-time shutting of drapes, and turning off lights: all of these are taken as examples of energy-consciousness.

A summary of energy-conscious responses to the questions appears in Table 7. There appears to be no correlation between energy-consciousness and living in the better-insulated houses. Therefore living habits should not be a factor biasing the heating consumption results of this survey in favour of HI's or LHI's. It is noteworthy that the people in this survey, who represent a good cross-section of today's home-buyers, claim to be highly aware of simple energy conservation techniques and this is reflected in their reported frequent usage of these techniques.

from results

The scatter of results in Fig. 2 indicates that, taken together, the factors not related to house envelope, ie. living habits, seasonal efficiency of furnace, and exposure/orientation, also strongly affect the heating bill. Since the initial selection of houses minimized differences in exposure/orientation for most, and the furnace steady-state testing infers that many may have similar seasonal efficiences (within the groups) it follows that differing living habits probably account for much of the scatter within the city groups in this survey.

The scatter is greatest, and the heating performance is poorest (per degree day) in the mildest area, Toronto. This agrees with other surveys of apartments and houses, and infers again that living habits are "tighter" and seasonal furnace efficiency is better where the winter is long and cold. In Ottawa and particularly Winnipeg it is most unlikely that windows are opened or left open into a January night, and most likely that furnaces face longer running cycles giving better average efficiencies. Other Scanada analyses on effects of door opernings indicate that frequent opening of the entry door does not have much effect on house heating consumption (and that an air-lock vestibule is not a significant energy saver). Door usage is not suggested as an important factor in the overall living habits that in total do show a strong effect particularly in the milder climate. (All Toronto HI's and the single-detached Ottawa HI's have vestibules.)

Figs. 2A and 3 are annotated with those living habits discernible from the householders' responses. Again a pattern is clear, suggesting that at least one primary "habit" has a strongly conserving effect: lowering the indoor temperature. The "ts" (substantial thermostat setback) and "pu" (substantial portion of house shut off to run cooler) habits accomplish that one end, and are associated with unusually low heat consumption. Similarily, the "nts" (no setback), and"ht" (higher temperature) habits are associated with high heat consumption. This does not suggest that other habits (substantial opening of windows, leaving furnace uncleaned or filters unchanged) do not also play substantial roles but this field survey was not able to delineate or distinguish between them.

CONCLUSIONS

1) Higher levels of insulation do reduce heating fuel consumption commensurately; the savings follow theory; high levels of insulation work in houses about as well as in the laboratory.

2) A high level of insulation in new houses (eg. r 3.5 and higher), as compared to moderate levels (eg. R 2.1), does not change overall air leakage characteristics or relative humidity (RH) and does not cause problems with the exception that signs suggestive of truss lifting do appear to be associated with high levels only (R 5.6 and higher, in this field survey).

3) A high level of insulation in new houses does not yield more uniform temperature, RH, or better "comfort" than does a moderate (1975 standard) level.

4) Living habits and seasonal furnace efficiency taken together (this field study generally could not separate their effects) do play a strong part in heating consumption, particularly so in the milder city, Toronto (probably due to "looser" habits and intermittent furnace cycling where the winter months are less steadily cold).

5) The lowering of indoor temperature is one living habit that appears to reduce heating bills sharply.

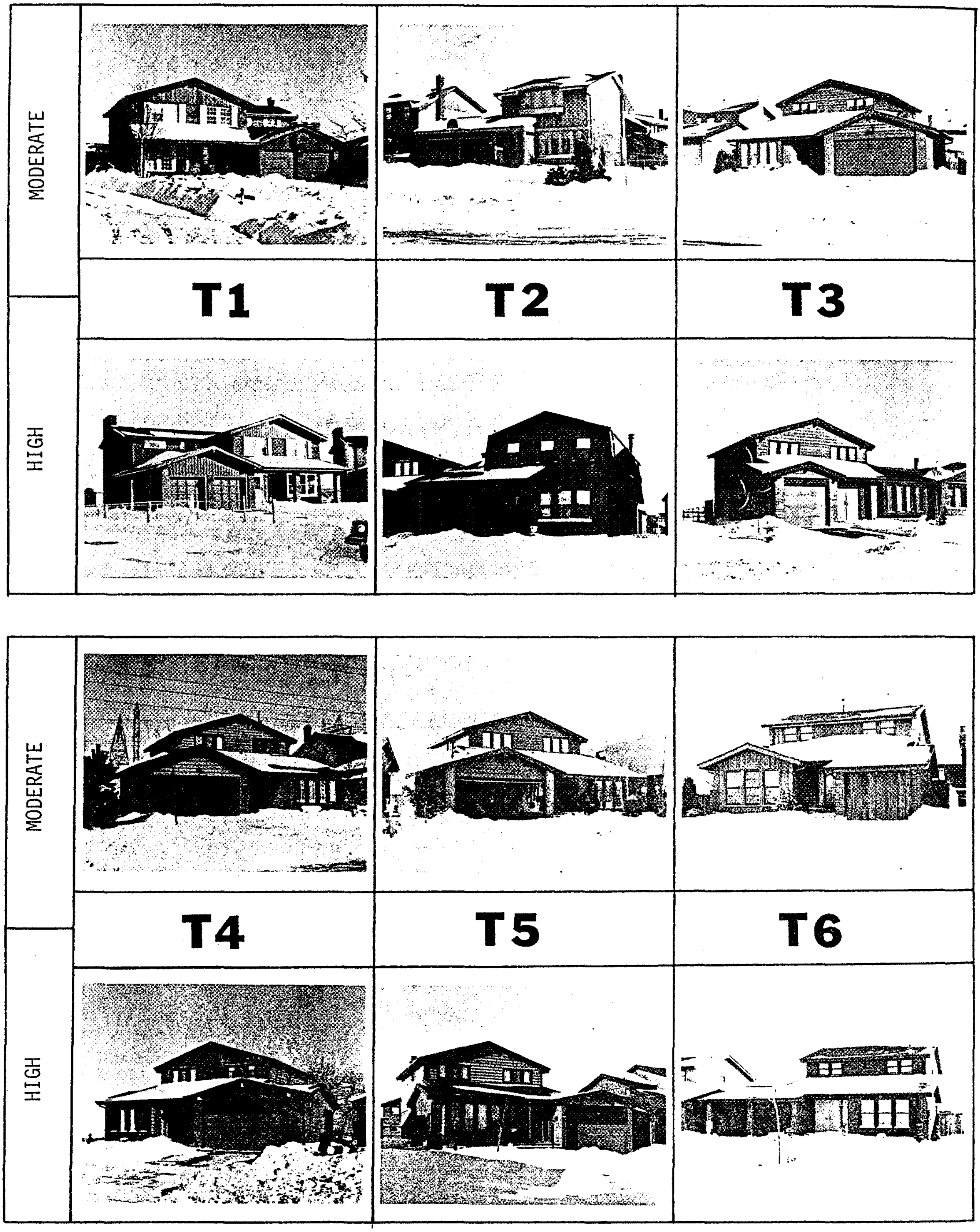


FIGURE 1A. TORONTO HOUSES

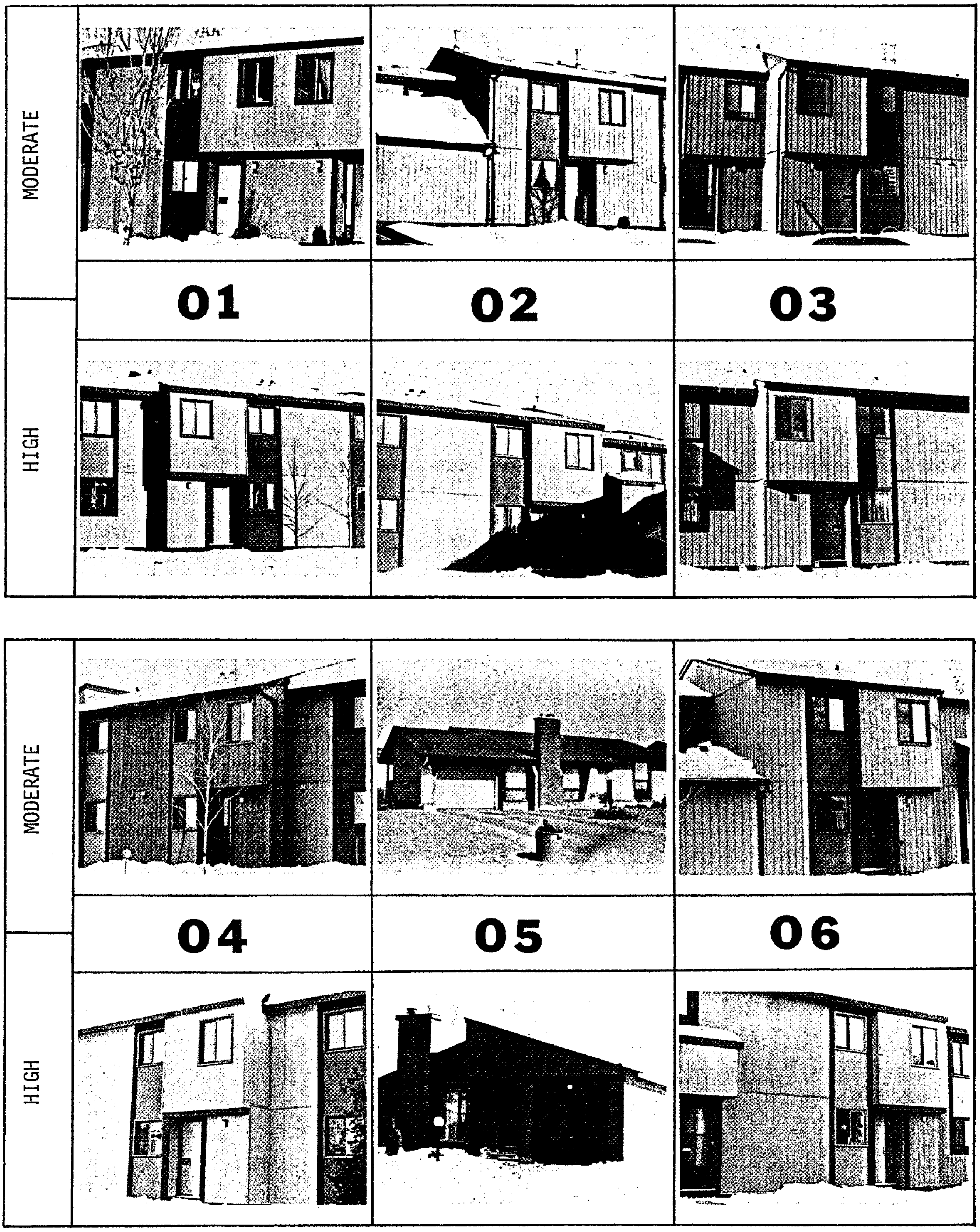


FIGURE 1B. OTTAWA HOUSES

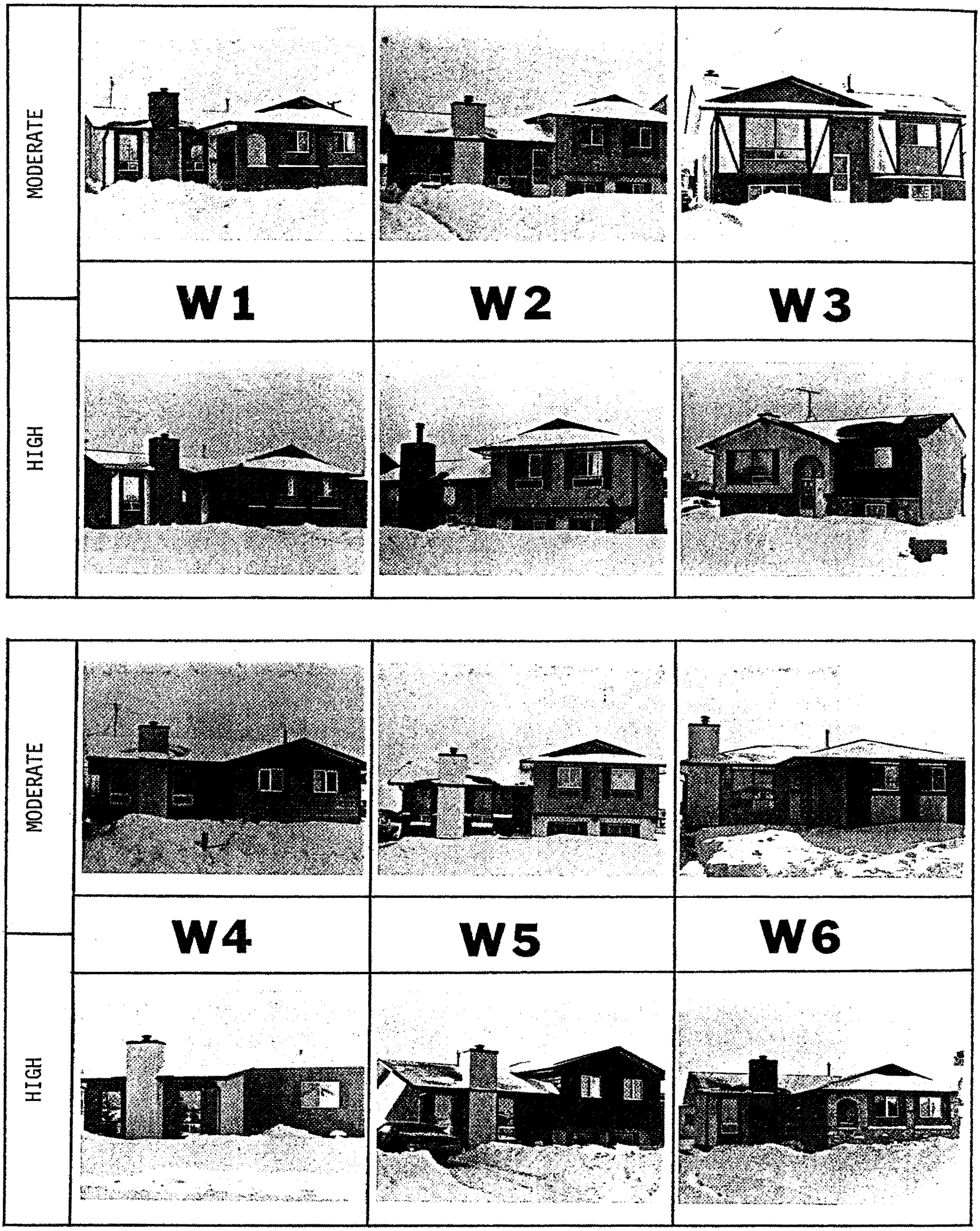


FIGURE 1C. WINNIPEG HOUSES

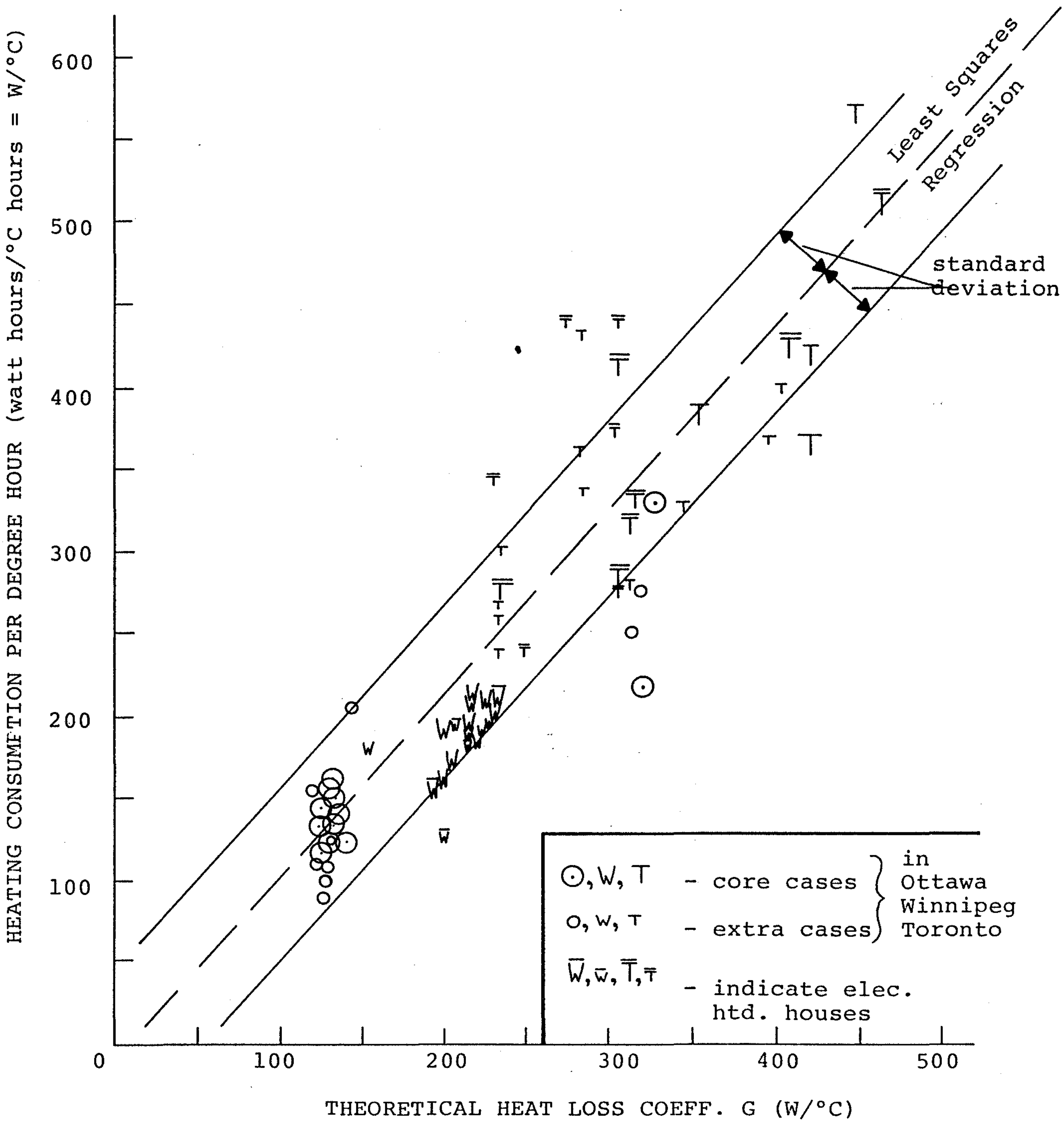


FIGURE 2. HEATING CONSUMPTION VS. THEORETICAL HEAT LOSS COEFF. G

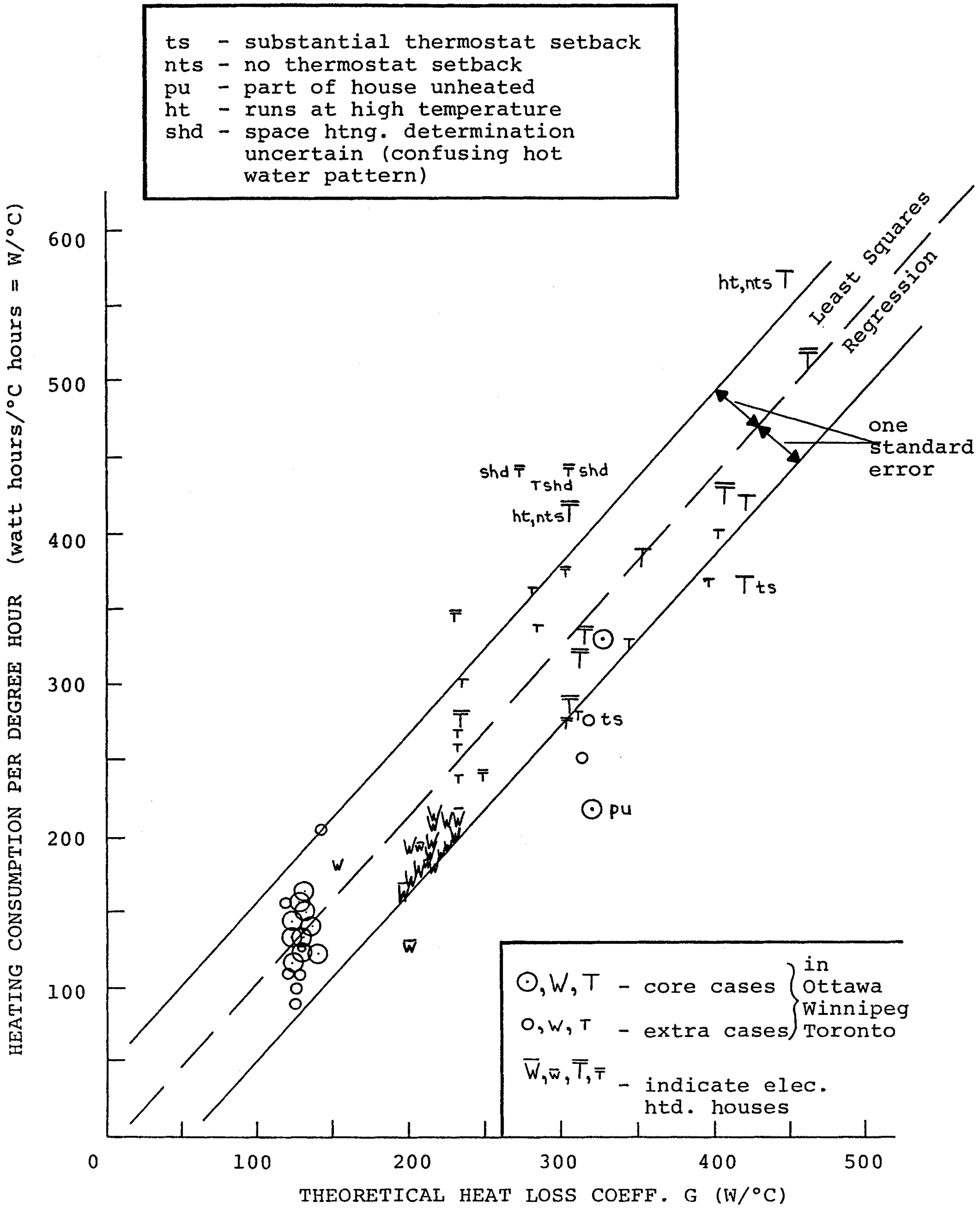


FIGURE 2A. HEATING CONSUMPTION VS. THEORETICAL HEAT LOSS COEFF. G (ANNOTATED)

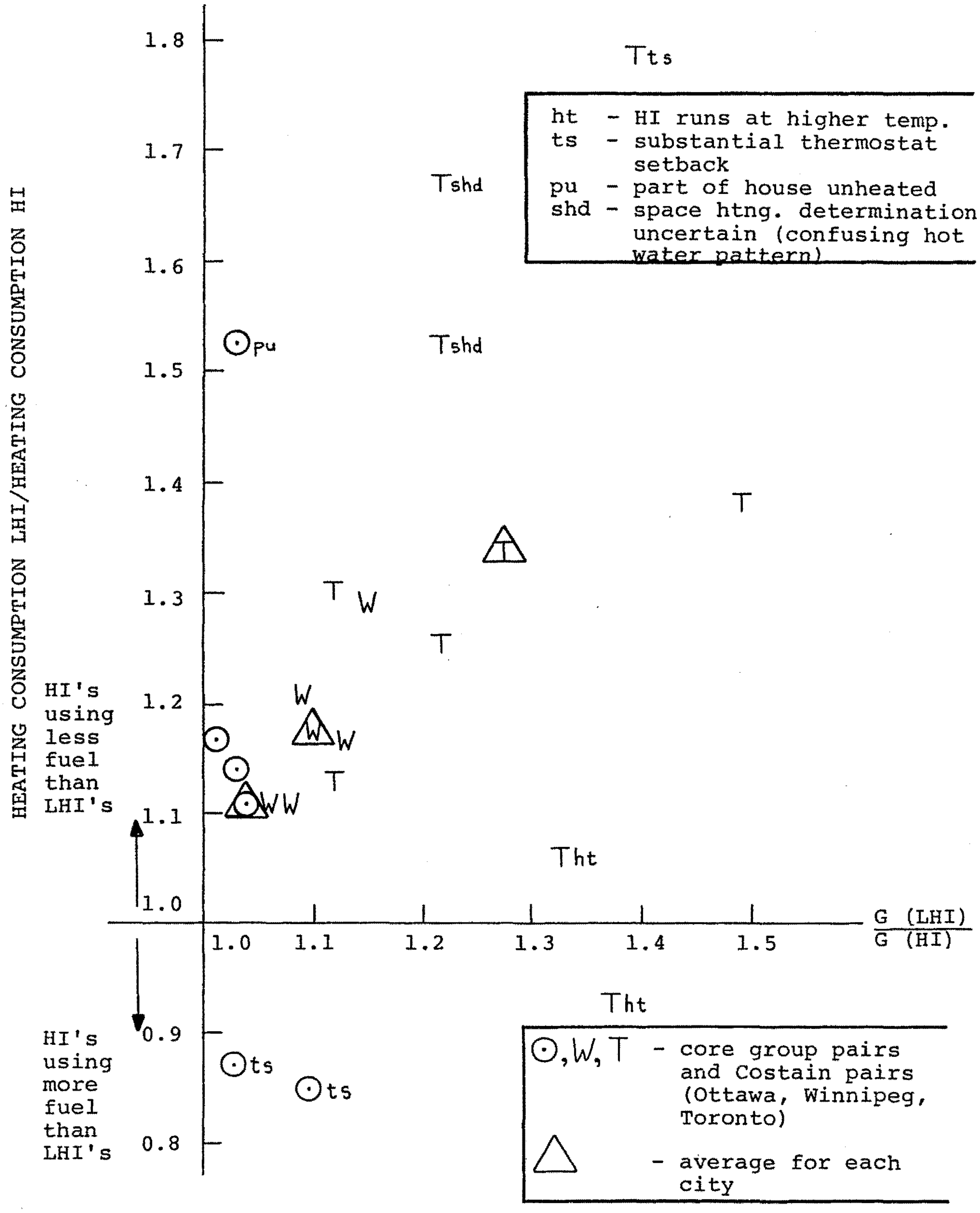


FIGURE 3. PAIRED HOUSES: HEAT CONSUMPTION RATIO VS. G RATIO, LHI/HI

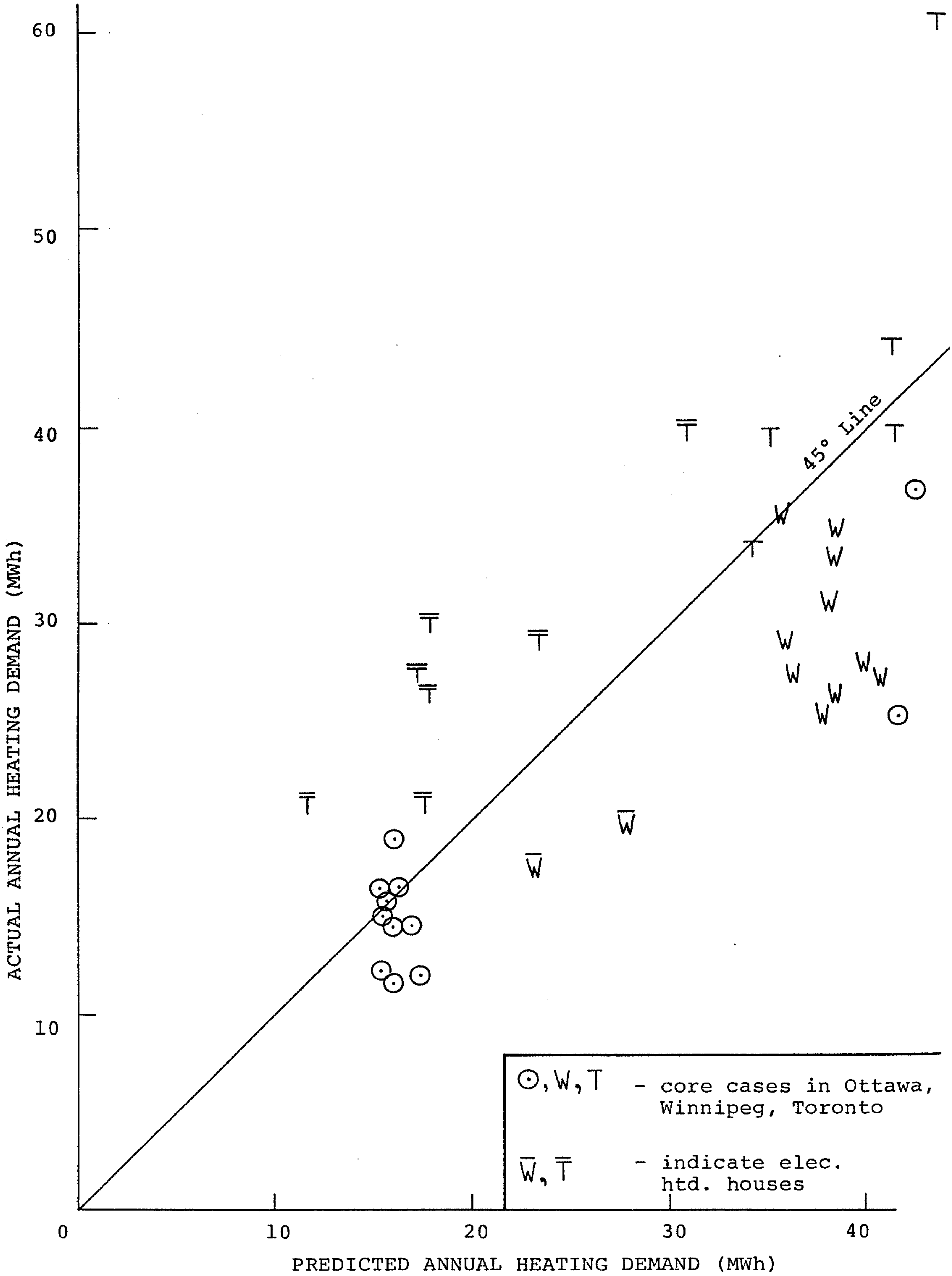


FIGURE 4. ACTUAL VS. PREDICTED ANNUAL HEATING DEMAND (MWh)

	Insulation Level:	Less Highly Insulated (LHI)	Highly Insulated (HI)
Toronto	Walls:	88.9mm (3 1/2") fibreglass batts; R2.3 (R13)	88.9mm (3 1/2") fibreglass batts; plus 38.1mm (1 1/2") Dow SM Insulating Sheathing; R3.5 (R20)
	Attic:	88.9mm (3 1/2") fibreglass batts; R2.3 (R13)	254mm (10") fibreglass batts; R5.8 (R33)
	Basement Walls:	no insulation	R1.4 (R8) beadboard to 0.9m(3 ft) below grade
Winnipeg	Walls:	88.9mm (3 1/2") fibreglass batts; R2.1 (R12)	139.7mm (5 1/2") fibreglass batts; R3.0 (R17)
	Attic:	Cellulose fibre; R7.2 (R41)	Cellulose fibre R7.2 (R41)
	Basement Walls:	R1.4 (R8) beadboard to 0.9m(3 ft) below grade	R1.4 (R8) beadboard to 0.9m(3 ft) below grade
Ottawa	Walls: rows:	88.9mm (3 1/2") fibreglass batts; R2.1 (R12)	88.9mm (3 1/2") fibreglass batts; R2.1 (R12)
	singles:	Fibreglass batts; R1.9 (R11)	88.9 (3 1/2") fibreglass batts; R2.1 (R12)
	Attics:	Fibreglass batts; R3.6 (R21)	Fibreglass batts; R5.6 (R32)
	Basement Walls: rows:	R1.2 (R7) beadboard to 0.9m (3 ft) below grade	R1.2 (R7) beadboard to 0.9m (3 ft) below grade
	singles:	no insulation	R1.2 (R7) beadboard to 0.9m (3 ft) below grade

Notes
1. R values represent the Total Resistance except for basement walls.
2. R values represent the "as built" and in most cases "as is" insulation levels. Only 5 of the 36 homes have added to these levels.
3. Imperial R values in brackets

TABLE 1. BUILDING CONSTRUCTION

Area	House Number	Type	Finished Floor Area M^2 (FT^2)	Building Volume M^3 (FT^3)	Orientation* (degrees)	G W/°C [Btu/hr°F]	Fuel Type Heat.	Fuel Type Ht.Water	No. of Occupants** Adults.	No. of Occupants** Child.
Toronto	T1	2 Storey	261 (2812)	1000(35386)	60 (NE)	465 (877)	Elec.	Elec.	2	3
	T2	2 Storey	172 (1852)	620(21855)	150 (SE)	355 (670)	Gas	Gas	2	3
	T3	2 Storey	190 (2050)	730(25725)	270 (W)	423 (798)	Gas	Gas	2	3
	T4	2 Storey	190 (2050)	730(25725)	190 (S)	422 (796)	Gas	Gas	2	2
	T5	2 Storey	190 (2050)	730(25725)	52 (NE)	346 (653)	Gas	Gas	2	2
	T6	2 Storey	190 (2050)	730(25725)	20 (N)	447 (843)	Gas	Gas	2	1
Ottawa	01	2 St.Row	101 (1088)	370(13020)	80 (E)	129 (243)	Gas	Gas	2	1
	02	2 St.Row	101 (1088)	370(13020)	90 (E)	135 (255)	Gas	Gas	2	1
	03	2 St.Row	101 (1088)	370(13020)	320 (NW)	139 (262)	Gas	Gas	1	1
	04	2 St.Row	101 (1088)	370(13020)	170 (S)	129 (243)	Gas	Gas	2	1
	05	Bungalow	117 (1263)	540(18941)	180 (S)	328 (619)	Gas	Gas	2	1
	06	2 St.Row	101 (1088)	370(13020)	170 (S)	128 (242)	Gas	Gas	2	2
Winnipeg	W1	Bungalow	106 (1136)	510(18160)	80 (E)	226 (426)	Gas	Gas	3	3
	W2	Spl.Lev.	141 (1520)	470(16624)	70 (E)	216 (408)	Gas	Gas	2	4
	W3	Bi-Level	120 (1296)	450(15956)	20 (N)	217 (409)	Gas	Gas	2	3
	W4	Bungalow	99 (1064)	480(17088)	130 (SE)	218 (411)	Gas	Gas	2	3
	W5	Spl.Lev.	141 (1520)	470(16624)	250 (W)	233 (440)	Elec.	Elec.	2	0
	W6	Bungalow	99 (1068)	480(17088)	330 (NW)	231 (436)	Gas	Gas	2	1

* Most Windowed Face

** LHI's (older than HI's) have 1/3 more occupants

TABLE 2A. SUMMARY OF HOUSING CHARACTERISTICS: LESS-HIGHLY-INSULATED

Area	House Number	Type	Finished Floor Area M^2 (FT^2)	Building Volume M^3 (FT^3)	Orientation* (degrees)	G W/°C [Btu/hr°F]	Fuel Type Heat.	Fuel Type Ht. Water	No. of Occupants Adults	No. of Occupants Child.
Toronto	T1	2 Storey	261 (2812)	1000 (35146)	100 (E)	416 (785)	Elec.	Elec.	2	2
	T2	2 Storey	172 (1852)	620 (21855)	150 (SE)	237 (447)	Elec.	Elec.	3	0
	T3	2 Storey	190 (2050)	740 (26068)	230 (SW)	307 (579)	Elec.	Elec.	4	0
	T4	2 Storey	190 (2050)	740 (26068)	280 (W)	318 (600)	Elec.	Elec.	2	3
	T5	2 Storey	190 (2050)	740 (26068)	140 (SE)	309 (583)	Elec.	Elec.	2	0
	T6	2 Storey	190 (2050)	740 (26068)	340 (N)	319 (602)	Elec. Heat Pump	Elec.	2	0
Ottawa	01	2 St.Row	101 (1088)	370 (13020)	80 (E)	125 (236)	Gas	Gas	2	2
	02	2 St.Row	101 (1088)	370 (13020)	80 (E)	131 (247)	Gas	Gas	1	1
	03	2 St.Row	101 (1088)	370 (13020)	350 (N)	126 (238)	Gas	Gas	2	0
	04	2 St.Row	101 (1088)	370 (13020)	170 (S)	131 (247)	Gas	Gas	1	1
	05	Bungalow	119 (1280)	600 (21120)	200 (S)	320 (604)	Gas	Gas	2	0
	06	2 St.Row	101 (1088)	370 (13020)	190 (S)	127 (240)	Gas	Gas	2	0
Winnipeg	W1	Bungalow	106 (1136)	510 (18160)	310 (NW)	214 (404)	Gas	Gas	2	1
	W2	Spl.Lev.	141 (1520)	470 (16624)	70 (E)	218 (411)	Gas	Gas	2	2
	W3	Bi-Level	120 (1296)	450 (15956)	180 (S)	199 (375)	Elec.	Elec.	2	3
	W4	Bungalow	100 (1080)	490 (17280)	30 (NE)	202 (381)	Gas	Gas	2	0
	W5	Spl.Lev.	141 (1520)	470 (16624)	160 (S)	202 (381)	Gas	Gas	2	2
	W6	Bungalow	106 (1136)	510 (18160)	120 (NW)	205 (387)	Gas	Gas	3	0

* Most Windowed Face

TABLE 2B. SUMMARY OF HOUSING CHARACTERISTICS: HIGHLY-INSULATED

LHI's	Toronto Good	Toronto Average	Toronto Poor	Ottawa Good	Ottawa Average	Ottawa Poor	Winnipeg Good	Winnipeg Average	Winnipeg Poor	Total Good	Total Average	Total Poor
Humidity Level*	3	2	1	3	2	1	0	5	1	6	9	3
Room Temperature	2	2	2	4	2	0	2	4	0	8	8	2
Floor Temperature	2	2	2	5	1	0	2	4	0	9	7	2
Heat Distribution	1	1	4	0	4	2	2	2	2	3	7	8
Odour	4	1	1	3	3	0	5	1	0	12	5	1
Drafts - Doors	2	2	2	2	3	1	0	3	3	4	8	6
- Windows	0	1	5	2	2	2	1	3	2	3	6	9
- Floor Area	1	5	0	3	3	0	2	4	0	6	12	0
- Fireplace	1	4	1	1	0	0	1	2	3	3	6	4
- Electrical Outlets	0	2	4	3	2	1	2	4	0	5	8	5
Total	16	22	22	26	22	7	17	32	11	59	76	40
%	26	37	37	47	40	13	28	54	18	34	43	23

HI's	Toronto Good	Toronto Average	Toronto Poor	Ottawa Good	Ottawa Average	Ottawa Poor	Winnipeg Good	Winnipeg Average	Winnipeg Poor	Total Good	Total Average	Total Poor
Humidity Level*	3	2	1	1	1	4	0	4	2	4	7	7
Room Temperature	1	4	1	3	1	2	3	3	0	7	8	3
Floor Temperature	2	3	1	4	1	1	2	4	0	8	8	2
Heat Distribution	2	1	2	1	4	1	2	3	1	5	8	5
Odour	5	1	0	3	3	0	2	4	0	10	8	0
Drafts - Doors	3	2	1	1	4	1	1	2	3	5	8	5
- Windows	3	1	2	1	3	2	1	2	3	5	6	7
- Floor Area	5	0	1	1	4	1	2	4	0	8	8	2
- Fireplace	4	2	0	0	0	1	0	3	3	4	5	4
- Electrical Outlets	3	1	2	0	4	2	1	3	2	4	8	6
Total	31	17	12	15	25	15	14	32	14	60	74	41
%	52	28	20	27	46	27	23	54	23	34	43	23

TABLE 3. REPORTED HOME COMFORT

* "Poor" Humidity meant house was too dry.

House Number	°C (°F) Mid Room Temp. Avg.	Max.	Min.	Thermostat Setting (°C)	% Relative Humidity Avg.	Max.	Min.
T1	24 (75)	26 (78)	19 (67	20	31	37	26
T2	22 (71)	26 (78)	17 (62)	21	28	34	24
T3	21 (69)	22 (72)	19 (66)	22	25	30	21
T4	19 (66)	20 (68)	16 (61)	17	33	36	30
T5	18 (65)	19 (67)	17 (62)	18	37	40	36
T6	22 (71)	23 (73)	18 (65)	20	29	31	25
Average	21 (70)	23 (73)	18 (64)	20	31	35	27
01	19 (67)	21 (69)	16 (61)	18	31	40	25
02	21 (70)	24 (75)	19 (67)	20	24	25	22
03	21 (70)	22 (72)	21 (70)	20	22	22	22
04	21 (70)	22 (72)	19 (67)	22	27	32	24
05	21 (70)	22 (72)	20 (68)	24	27	34	24
06	21 (69)	23 (73)	19 (66)	20	32	34	29
Average	21 (69)	22 (72)	19 (67)	21	27	31	24
W1	21 (69)	22 (71)	19 (67)	22	29	32	27
W2	22 (71)	23 (73)	21 (70)	21	25	27	23
W3	21 (69)	22 (71)	19 (67)	21	21	23	19
W4	21 (69)	21 (70)	21 (69)	23	23	28	14
W5	20 (68)	22 (72)	18 (64)	21	37	43	33
W6	21 (69)	22 (71)	18 (64)	20	30	34	26
Average	21 (69)	22 (71)	19 (67)	21	28	31	24

TABLE 4A. TEMPERATURE AND RELATIVE HUMIDITY: LESS HIGHLY INSULATED

House Number	°C (°F) Mid Room Temp. Avg.	Max.	Min.	Thermostat Setting (°C)	% Relative Humidity Avg.	Max.	Min.
T1	21 (70)	23 (74)	19 (67)	20	34	37	29
T2	22 (72)	24 (76)	18 (65)	21	27	33	13
T3	21 (69)	22 (72)	19 (67)	23	24	30	21
T4	19 (67)	21 (69)	18 (65)	18	34	48	30
T5	21 (70)	22 (71)	19 (67)	22	23	27	0
T6	20 (68)	21 (69)	19 (66)	20	36	38	32
Average	21 (69)	22 (72)	19 (66)	21	30	36	21
01	22 (72)	23 (74)	19 (67)	20	32	36	28
02	22 (71)	23 (74)	19 (66)	20	19	21	17
03	24 (75)	24 (76)	22 (72)	20	23	25	22
04	21 (70)	22 (71)	18 (65)	20	24	25	23
05	20 (68)	22 (71)	18 (65)	20	27	30	23
06	21 (69)	22 (72)	18 (64)	20	29	36	4
Average	22 (71)	23 (73)	19 (67)	20	26	29	20
W1	21 (70)	22 (72)	18 (64)	21	27	30	24
W2	22 (72)	23 (74)	21 (69)	20	23	28	22
W3	20 (68)	23 (74)	18 (64)	21	35	54	20
W4	22 (71)	23 (73)	18 (64)	21	28	32	22
W5	22 (71)	25 (77)	21 (69)	18	30	33	26
W6	21 (69)	23 (74)	18 (65)	20	24	31	20
Average	21 (70)	23 (74)	19 (66)	20	28	35	22

TABLE 4B. TEMPERATURE AND RELATIVE HUMIDITY : HIGHLY INSULATED

	LHI			HI		
Pair	Equiv. Leakage Area		Inferred Air Change	Equiv. Leakage Area		Inferred Air Change
	(m^2)	(ft^2)	AC/hour	(m^2)	(ft^2)	AC/hour
T1	0.17	(1.82)	.13			
T2	0.16	(1.69)	.19	0.13	(1.36)	.15
T3	0.18	(1.93)	.20	0.19	(2.02)	.21
T4	0.18	(1.90)	.19	0.21	(2.22)	.26
T5	0.16	(1.72)	.17	0.19	(2.05)	.22
T6	0.20	(2.10)	.23	0.21	(2.29)	.28
01	0.13	(1.43)	.26	0.13	(1.39)	.26
02	0.14	(1.55)	.29	0.14	(1.55)	.29
03	0.13	(1.43)	.26	0.13	(1.43)	.26
04	0.14	(1.47)	.27	0.15	(1.66)	.31
05	0.09	(0.92)	.11	0.15	(1.56)	.18
06	0.13	(1.39)	.25	0.12	(1.33)	.24
W1	0.08	(0.87)	.11	0.09	(0.96)	.17
W2	0.08	(0.87)	.12	0.09	(0.96)	.13
W3	0.08	(0.84)	.12			
W4	0.09	(0.96)	.13	0.10	(1.09)	.15
W5	0.08	(0.82)	.12	0.09	(1.02)	.14
W6	0.09	(0.97)	.13	0.10	(1.06)	.14

TABLE 5. AIR LEAKAGE TEST RESULTS AND INFERRED "AVERAGE AIR CHANGE"

Q. Was energy consumption a consideration in the selection and purchase of your home?

A.

	LHI	HI
yes	10	12
no	7	5
no ans.	1	1

Q. Do you feel your home is presently well-insulated and energy-efficient?

A.

	LHI	HI
yes	3	11
no	12	6
unsure	3	1

Q. Do you plan to make any further changes to your home in the near future to make it more thermally efficient?

A.

	LHI	HI
yes	12	12
no	5	6
no ans.	1	

Q. What influenced your most recent actions to conserve energy?

A.*

	LHI	HI
Gov't	4	1
Fuel Bills	15	15
Personal Need	2	5
Energy Publ.	5	1

*(Some people checked more than one category.)

TABLE 6. "ENERGY AWARENESS"

Energy-Conscious?

Category	LHI's yes	LHI's no	HI's yes	HI's no
Fireplace dampers	13	0	13	0
Thermostat setback	10	8	10	8
Furnace servicing	8	9	1	4
Exterior doors	12	6	13	5
Interior lighting	14	4	16	2
Windows	14	4	17	1
Drapes	17	1	18	0
Exhaust Fans	13	0	9	3
Totals:	101	32	97	23
%:	76	24	81	19

TABLE 7. ENERGY-RELATED LIVING HABITS

House	Wall Area	Wall R	Attic Area	Attic R	Window Area	Window R	Door Area	Door R	Other Area	Other R	Basement Perim	Basement Ht Loss Factor	Basement Ab. Gr.	Basement Window Area	Basement Window R	Tot. Gas (ccf)	Tot. Elec. (kWh)	Summer Gas (3mo) (ccf)	Summer Elec. (3mo) (kWh)	Stove	Refrig.	Washer	Dryer	Freezer	Dish-Washer	Elec. Kettle	Stereo	Humid-ifier	T.V. B&W	T.V. Col	Car Bl. Heater	Total Heating Season °C Days
	sq.m.	SI	sq.m.	SI	sq.m.	SI	sq.m.	SI	sq.m.	SI	m.		sq.m.	sq.m.																		
HIGHLY INSULATED HOUSES																																
T1	196	3.6	148	5.8	42	.3	4	1.0	25	3.7	54	0.92	7	2.2	.3		41710		2740	1	2	1	1	1	1	1	2	1	0	1	0	4319
T2	152	3.5	86	5.8	24	.4	4	1.1	18	3.7	41	0.92	6	0.7	.3		30890		2390	1	1	1	1	0	1	1	0	1	1	0	1	4372
T3	181	3.5	100	5.8	26	.3	5	1.0	25	4.1	48	0.92	7	2.2	.3		13950		5750	1	2	1	1	1	1	1	3	0	1	2	0	1400
T4	181	3.5	100	5.8	26	.3	5	1.4	25	4.1	48	0.92	7	2.2	.3		39130		3160	1	1	1	1	1	1	1	1	1	0	1	0	4372
T5	181	3.5	100	5.8	26	.3	5	1.0	25	4.1	48	0.92	7	2.2	.3		32630		3560	1	1	1	1	1	1	1	1	1	0	1	0	4230
T6	178	3.5	100	5.8	25	.3	5	1.4	25	4.1	48	0.92	7	2.2	.3		28040		6610	1	1	1	1	0	1	1	1	1	0	1	0	4161
W1	103	3.0	106	7.3	10	.4	3	1.4			45	1.14	24	.7	.2	1567		84		1	1	1	1	1	0	1	1	0	1	1	0	8296
W2	112	3.0	97	7.3	16	.3	2	1.3			41	1.14	19	.3	.3	1588		90		1	1	1	1	1	1	0	2	0	1	1	2	8296
W3	132	3.0	90	7.3	18	.5	2	1.4			39	1.14	6	0			19330		NA	1	1	1	1	1	0	1	0	0	0	1	1	4739
W4	92	3.0	100	7.3	11	.5	3	1.3			44	1.14	27	.8	.3	1176		87		1	1	1	1	1	1	1	1	1	0	1	2	5603
W5	112	3.0	97	7.3	16	.5	2	1.3			41	1.14	19	0		1017		NA		1	1	1	1	1	1	1	1	1	0	1	2	6059
W6	103	3.0	106	7.3	10	.5	3	1.4			45	1.14	24	.7	.3	1075		99		1	1	1	1	1	0	1	1	0	0	1	2	5698
01	44	2.1	51	5.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	562		NA		1	1	1	0	0	0	0	1	0	2	0	0	4112
02	47	2.1	51	5.6	10	.3	5	1.5	.7	2.2	12	1.14	3	.4	.3	697		NA		1	1	1	1	1	0	0	1	0	1	0	0	4112
03	44	2.1	51	5.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	617		NA		1	1	1	1	0	1	1	1	0	0	1	0	4112
04	44	2.1	51	5.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	738		NA		1	1	1	1	0	0	1	1	0	0	1	0	4210
05	110	2.1	119	5.6	17	.3	2	1.3	7	1.4	49	1.14	11	3	.3	1123		NA		1	2	1	1	1	1	1	1	0	0	1	1	4896
06	47	2.1	51	5.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	628		NA		1	1	1	1	0	0	1	1	0	1	0	0	4112
LESS HIGHLY INSULATED HOUSES																																
T1	197	2.3	151	2 3	193	.3	4	1.3	25	2.4	54	1.14	8	2	.3		38280		6920	1	2	1	1	1	1	1	1	1	1	2	0	3464
T2	152	2.2	86	2.3	22	.3	4	1.3	21	2.4	40	1.65	6	1	.3	1653		139		1	1	1	1	0	1	1	1	1	1	0	0	4319
T3	181	2.2	92	2.3	26	.3	5	0.7	32	2.3	48	30%:0.92 70%:1.65	7	2	.3	1654		68		1	2	1	1	1	1	1	1	1	1	1	0	4319
T4	181	2.2	100	4.8	26	.3	5	0.7	25	2.3	48	1.65	7	2	.3	1535		198		1	1	1	1	1	1	1	1	1	1	1	0	4356
T5	181	2.2	100	6.3	26	.3	5	1.3	25	2.3	48	0.92	7	2	.3	1383		126		1	2	1	1	0	1	1	1	1	0	1	0	4331
T6	178	2.2	100	2.3	25	.3	5	0.7	25	2.3	48	1.65	7	2	.5	2271		176		1	1	1	1	1	1	1	1	1	0	1	1	4319
W1	103	2.1	106	7.3	10	.3	3	1.4			45	1.14	24	1	.3	2102		138		2	2	1	1	0	0	0	3	0	0	1	3	9161
W2	112	2.1	97	7.3	16	.5	2	1.4			41	1.14	19	.3	.2	1916		114		1	1	1	1	1	1	1	1	0	2	0	1	8026
W3	132	2.1	90	7.3	18	.5	2	1.4			39	1.14	6	0		1831		132		1	1	1	0	1	0	1	1	0	1	1	1	8154
W4	104	2.1	99	7.3	12	.5	3	1.4			43	1.14	26	1	.3	1243		84		1	1	1	1	1	1	1	2	0	0	1	2	5603
W5	112	2.1	97	7.3	16	.5	2	1.3			41	1.14	6	.3	.3		52490		2650	1	1	1	1	1	0	1	1	0	0	1	2	10403
W6	94	2.1	99	7.3	11	.3	3	0.6			44	1.14	31	1	.3	1075		72		1	1	1	1	1	0	1	1	0	0	1	1	9161
01	44	2.1	51	3.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	1437		75		1	1	1	1	1	1	1	1	0	1	0	0	8854
02	46	2.1	51	3.6	10	.3	5	1.3	.7	2.2	12	1.14	3	.4	.3	1553		84		1	1	1	1	0	0	1	1	0	1	0	0	9124
03	53	2.1	51	3.6	10	.3	5	1.5	.7	2.2	13	1.14	3	.4	.3	1394		81		1	1	1	1	0	0	0	1	0	0	1	0	9124
04	44	2.1	51	3.6	10	.3	5	1.5	.7	2.2	12	50%:1.14 50%:0.92	3	.4	.3	1497		NA		1	1	1	1	0	0	1	1	1	0	1	0	9818
05	91	2.1	117	3.6	16	.3	3	0.8	7	1.4	46	1.14	11	1	.3	6437		NA		1	1	1	1	1	1	0	1	0	0	2	1	19987
06	49	2.1	51	3.6	10	.3	5	1.3	.7	2.2	12	0.92	3	.4	.3	1785		NA		1	1	1	1	0	0	1	1	0	1	0	0	9557

NA - Not Available

TABLE 8. MASTER TABLE: HOUSE CHARACTERISTICS AND ACTUAL ENERGY CONSUMPTION

Appendix 1

HOMEOWNER QUESTIONNAIRE

Scanada

Date ____________________ 19 ___ Building No. __________

Home Owner ______________________________________ Project No. __________

Number of Adults __________ Children ______________

Ages ______________

Street ______________________________________

City/Town ______________________ Province ______________________

Postal Code ______________________ Telephone No. ______________________

Changes To Home Since Purchase:

- Insulation:

Have you added insulation to your	Yes	No	Approx. Date
- walls?			
- ceiling/attic?			
- basement?			
- floor (over unheated area)?			

If you answered "Yes" to all or any portion of the question above, please indicate what type and thickness of insulation was used.

Insulation Type	Insulation Thickness (Inches)			
	Wall	Ceiling/ Attic	Basement	Floor (over unheated area)
Batts - Fiberglass				
- Rockwool				
Slab Insulation - Styrofoam				
- other ______				
Blown Insulation - Foam				
- Cellulose				
- Fiberglass				
Other ______				

Have you added insulation to any other area of your home?

Yes ☐ Please specify ______________________________________

____

No ☐

 Building No. ___________

• Storm Doors/Windows:

Have you added storm doors and/or storm windows to your home? Yes ☐ No ☐

If "Yes" - how many were added?

Storm Windows - all ☐ only _____ of _____ windows

Storm Doors - all ☐ only _____ of _____ doors

• Alterations/Additions:

Have there been any other alterations or additions to your home such as;

a porch enclosure? Yes ☐ No ☐

a room in attic? Yes ☐ No ☐

a room above garage? Yes ☐ No ☐

other? - please specify ______________________________

____

____

• Other Home Improvements Related To The Building's Enclosure:

Have you improved the thermal status (insulation) of your home in any way not previously mentioned? (i.e. triple glazed windows etc.)

____

____

• Space Heating Systems:

• Principal System: (This section refers to the heating system in your home that provides most of your heat)

On the following table please check the appropriate square to describe your heating system.

Heating With	Type of Fuel Used		
	Oil	Gas	Electricity
Steam or Hot Water			
Hot Air			
Electricity	N.A.	N.A.	

Please indicate the size (capacity, rating) of your primary heating system

____

 Building No. ____________

Have you made any changes or additions to your present heating system in order to improve efficiency and reduce fuel consumption? Yes ☐ No ☐

If "Yes" please check actions taken :

		When?
Reduce burner nozzle size	☐	____________
Insulate hot air ducts	☐	____________
Addition of flue heat recovery device	☐	____________
Addition of positive chimney damper	☐	____________
Adjustment of fan operating thermostat	☐	____________
Installed automatic "set back" thermostat	☐	____________

Other - please specify ____

____

Heating And Appliance Energy Consumption

In order to complete the energy analysis on your home we must have a breakdown of gas (if applicable) and electrical consumption to show actual energy use (even electricity consumed by lights and appliances contributes toward heating your home).

Please record the information from your utility bills in the space below or, if you prefer, simply enclose your old bills along with the complete questionnaire and we will return them by mail. We are interested in the period from January 1977 to the present or whatever portion of that time you have occupied your house. (If you no longer have this information, please sign the statement at the end of the questionnaire so that we may obtain your records directly from the utilities).

ELECTRICAL CONSUMPTION				GAS CONSUMPTION			
Service to or date read	Hydro KW-H	Charges (Net)		Date Read	Period	Gas (100 cu.ft.)	Charges: Gas used this month
		Hydro	Total				

• Fireplaces:

How many fireplaces does your home have? ____________

Please check type(s): Heatilator Type ☐

Franklin ☐

Metal Free Standing ☐

Solid Masonry ☐

Other ____

Please check type(s) of enclosure(s): Open Screen ☐

Glass Door ☐

Metal Door ☐

How many fireplaces are equipped with dampers? ________

When fireplace is not in use are dampers kept closed? Yes ☐ No ☐

How many chimneys does your home have? ___________

Type (metal, masonry, etc.) ____________________

• Domestic Hot Water Heating Systems:

What type of fuel does your hot water heater use? oil ☐ gas ☐ electricity ☐

What is the capacity of your hot water tank? _____________ gallons

Is your hot water heater owned ☐ or rented ☐ ?

• Electrical Service:

Please define your electrical service as fully as possible according to the following headings.

number of amperes ____

number of circuits ____

special wiring ____

special equipment ____

What has your electrical consumption been in kWh for the last 3 heating seasons?

	Consumption	Cost
Oct. 75 - April 76	__________ kWh	$_____._____
Oct. 76 - April 77	__________ kWh	$_____._____
Oct. 77 - April 77	__________ kWh	$_____._____

Does your electric bill include electric heating costs? Yes ☐ No ☐

• Major Appliances:

Please indicate which appliances you have in your home, the type of fuel required and their age.

Appliance	Number	Fuel	Age
Stove	_____	___________	_____
Fridge	_____	___________	_____
Washer	_____	___________	_____
Dryer	_____	___________	_____
Freezer	_____	___________	_____
Dishwasher	_____	___________	_____
Microwave Oven	_____		_____
Electric Kettle	_____		_____
Stereo	_____		_____
Humidifier	_____		_____
Television - B&W	_____		_____
- Colour	_____		_____
Car Block Heater	_____	___________	_____

If you have a dryer is it vented to the outside or to the inside? ___________

Are there any exhaust fans in your home? (i.e. in the kitchen, bathroom or attic)

Yes ☐ No ☐ If "Yes" please specify ____________________

____

Living Habits And Attitudes:

• Thermostat:

What is the average winter temperature setting of your thermostat?

during daytime __________ ^oF or __________ ^oC

during nightime __________ ^oF or __________ ^oC

• Heating System:

How often is your heating system professionally serviced? __________ times/year.

Do you feel that the number of times your furnace is serviced is adequate?

Yes ☐ No ☐ Unsure ☐

Building No. ___________

Is the garage in your home heated? Yes ☐ No ☐

If "Yes" what would its average winter temperature be? ____________

- **Home Comfort:**

Please assess the comfort level within the main living area of your home related to each of the following criteria during recent heating seasons.

	Good	Average	Poor
Humidity Level	___	___	___
Room Temperature	___	___	___
Floor Temperature	___	___	___
Heat Distribution	___	___	___
Odour	___	___	___
Drafts - Doors	___	___	___
- Windows	___	___	___
- Floor Area	___	___	___
- Fireplace	___	___	___
- Electrical Outlets	___	___	___

For any criteria which has been marked "Poor" please comment:

____

____

____

- **Living Habits:**

The following habits all consume and/or release energy during the <u>heating</u> season. Please review the habits listed below and comment as necessary:

Does your family make a conscious effort to;

- reduce the number of times that the exterior doors are opened? Yes ☐ No ☐
- reduce the number of lights on at one time? Yes ☐ No ☐

Approximately how many;

- showers are taken/day? ______
- baths are taken/day? ______
- laundries are washed/day? ______
- times are dishes washed/day? ______
- hours/day is stove used in cooking? ______
- hours/day is oven used in baking? ______

Building No. ______

Are windows periodically left open in your home? Yes ☐ No ☐

If "Yes" how many are left open

- during daytime? ______
- at night? ______

Do you tend to close drapes at night? Yes ☐ No ☐

Approximately how many days is your fireplace used per week? ______

If your home uses auxiliary heating, how many hours/day is it required? ______

Are exhaust fans used only when necessary in the;

kitchen Yes ☐ No ☐

bathroom(s) Yes ☐ No ☐

attic Yes ☐ No ☐

- Attitudes and Opinions:

Was energy consumption a consideration during the selection and purchase of your home? Yes ☐ No ☐

Do you feel that your home is presently well insulated and energy efficient?

Yes ☐ No ☐ Unsure ☐

Have problems such as cracks, leaks, condensation, or dust marking on interior walls been a problem?

Yes ☐ No ☐

If "Yes" please comment: ______

______

______

______

______

What influenced your most recent actions to conserve energy?

Government ☐
Private Industry ☐
Rising Fuel Bills ☐
Neighbour or Friend ☐
Personal Need ☐
Energy Publications ☐
Other (please comment) ______

Do you plan to make any further changes to your home in the near future to make it more thermally efficient?

Yes ☐ No ☐

Building No. ________

If "Yes" what changes do you intend to make to your home?

____

____

____

____

____

____

We would be pleased to have our home included in your study and hereby release our utility records to Scanada Consultants for use in their energy analysis.

Answered By: ____________________ Date: ____________________

Appendix 2

FURNACE EFFICIENCY TESTING

The Furnace Efficiency Testing

A steady-state performance test was conducted on each gas furnace according to the method described in Table 8. The actual calculation of the steady-state furnace efficiency utilized graphs plotted by J. Chi and G. Kelly and included in their paper "A Method for Estimating the Seasonal Performance of Residential Gas and Oil-Fired Heating Systems".* (Despite the title, neither this paper nor any other work yielded a practicable method for obtaining the probable seasonal efficiency for these cases).

The size and rating of each gas furnace as well as the measured stack temperature, CO_2 concentration and calculated efficiency are presented in Tables 9A and 9B.

Perhaps the most significant factor to notice about the furnace ratings is that identical furnaces were installed in both LHI's and HI's. Since the furnaces in Canadian houses are already oversized, this slight further oversizing in the HI's could lead to a further decrease in seasonal efficiency. This factor can have little effect in this study however since the only major difference in insulation level between LHI's and HI's occurs in Toronto where the HI's are electrically heated.

---

* Since the furnaces incorporate integral draft hoods, the more usual Bacharach method of testing could not be used.

1. Record the temperature of the furnace room.

2. Punch a small hole in the stack (about 6 inches above where the stack is connected to the furnace and upstream from the draft hood) and insert the stack thermometer.

3. Turn the thermostat up to turn the furnace on. Record the stack temperature when it has reached its highest steady-state value.

4. Remove the stack thermometer and insert the sampling tube of the gas analyzer. Take a gas sample and determine its CO_2 concentration.

5. From a graph (Chi and Kelly) relating the ratio of total combustion to stoichiometric air ($R_{T,S}$) to CO_2 concentration for various fuels, determine $R_{T,S}$ for the natural gas furnace.

6. Use $R_{T,S}$ and $T_{S,SS}$ (the stack temperature minus the room temperature) and another graph (Chi and Kelly) to determine $L_{S,SS,A}$, the steady-state sensible heat loss.

7. Chi and Kelly suggest that a value of 9.91 represents a typical latent heat loss for natural gas.

8. The steady-state furnace efficiency then is calculated to be:

$$N_{SS} = 100 - L_{S,SS,A} - 9.91$$

TABLE 8. STEADY-STATE PERFORMANCE TESTING OF GAS FURNACES

House Number	Furnace	Steady State Stack Temp. (°F)	CO_2 %	Steady State Furnace Efficiency
T1	Electric Resistance			
T2	Gas 105 MBTUH Input	450	3.25	65.1
T3	Gas 105 MBTUH Input	382	4.0	73.0
T4	Gas 105 MBTUH Input	325	3.0	72.1
T5	Gas 120 MBTUH Input	390	3.6	70.9
T6	Gas 120 MBTUH Input	405	4.0	71.9
01	Gas 75 MBTUH Input	240	3.5	79.7
02	Gas 75 MBTUH Input	255	3.0	78.1
03	Gas 75 MBTUH Input	245	3.0	78.8
04	Gas 75 MBTUH Input	280	3.0	76.3
05	Gas (Input Cap.NA)	390	5.0	76.1
06	Gas 75 MBTUH Input	180	4.0	84.0
W1	Gas 100 MBTUH Input	320	4.0	76.6
W2	Gas 125 MBTUH Input	300	4.0	77.9
W3	Gas 100 MBTUH Input	290	3.0	75.8
W4	Gas 100 MBTUH Input	365	4.25	75.3
W5	Electric Resistance			
W6	Gas 100 MBTUH Input	285	4.5	79.5

TABLE 9A. FURNACE EFFICIENCY : LESS HIGHLY INSULATED

House Number	Furnace	Steady State Stack Temp. (°F)	CO_2 %	Steady State Furnace Efficiency
T1	Electric Resistance			
T2	" "			
T3	" "			
T4	" "			
T5	" "			
T6	Electric Resistance plus Heat Pump			
01	Gas 75 MBTUH Input	245	2.5	74.3
02	Gas 75 MBTUH Input	270	3.25	77.2
03	Gas 75 MBTUH Input	265	3.5	78.5
04	Gas 75 MBTUH Input	260	2.5	72.8
05	Gas 100 MBTUH Input	310	4.0	77.0
06	Gas 75 MBTUH Input	250	3.0	78.2
W1	Gas 100 MBTUH Input	300	3.5	76.0
W2	Gas 125 MBTUH Input	300	3.5	76.2
W3	Electric Resistance			
W4	Gas 100 MBTUH Input	300	4.5	78.5
W5	Gas 125 MBTUH Input	340	3.25	72.7
W6	Gas 100 MBTUH Input	280	3.5	77.1

TABLE 9B. FURNACE EFFICIENCY: HIGHLY INSULATED

Appendix 3

AIR LEAKAGE TESTING AND FIRST ESTIMATION OF AVERAGE AIR CHANGE RATE

AIR LEAKAGE TESTING

The air leakage test subjects the house to a negative pressure (calibrated exhaust fan) and determines a gross leakage "hole" (equivalent leakage area) by the relationship of air flow rate to pressure differential. The pressure differential ΔP, inside to outside, is measured with a manometer. For a given exhaust air flow rate, Q, and pressure difference, ΔP, an equivalent leakage area, ELA, can be calculated from the formula:

$$ELA = \frac{Q}{2406 \sqrt{\Delta P}}$$

The ELA is based on the assumption that all leaks taken together behave as one sharp-edged orifice. This is not true, but the ELA expression does form a convenient "house characteristic" that can be compared with other houses.

While the negative pressure is maintained the technician can locate air leaks by feel or (in winter) by thermography. Thus the leakage test is a qualitative tool as well as a somewhat quantitatively comparative tool.

Air leakage tests were conducted on 34 of the 36 core cases in this study. (The remaining 2 houses could not be tested due to the personal schedules of the occupants). Eight houses were tested with National Research Council equipment (see Figure 5A) and the other twenty-six houses were tested with Ontario Hydro equipment (see Figure 5B).

The N.R.C. equipment consists of a vane axial fan of 3000 cfm capacity connected to a metal duct, 1 foot in diameter and 12 feet in length. A damper at the inlet of the duct

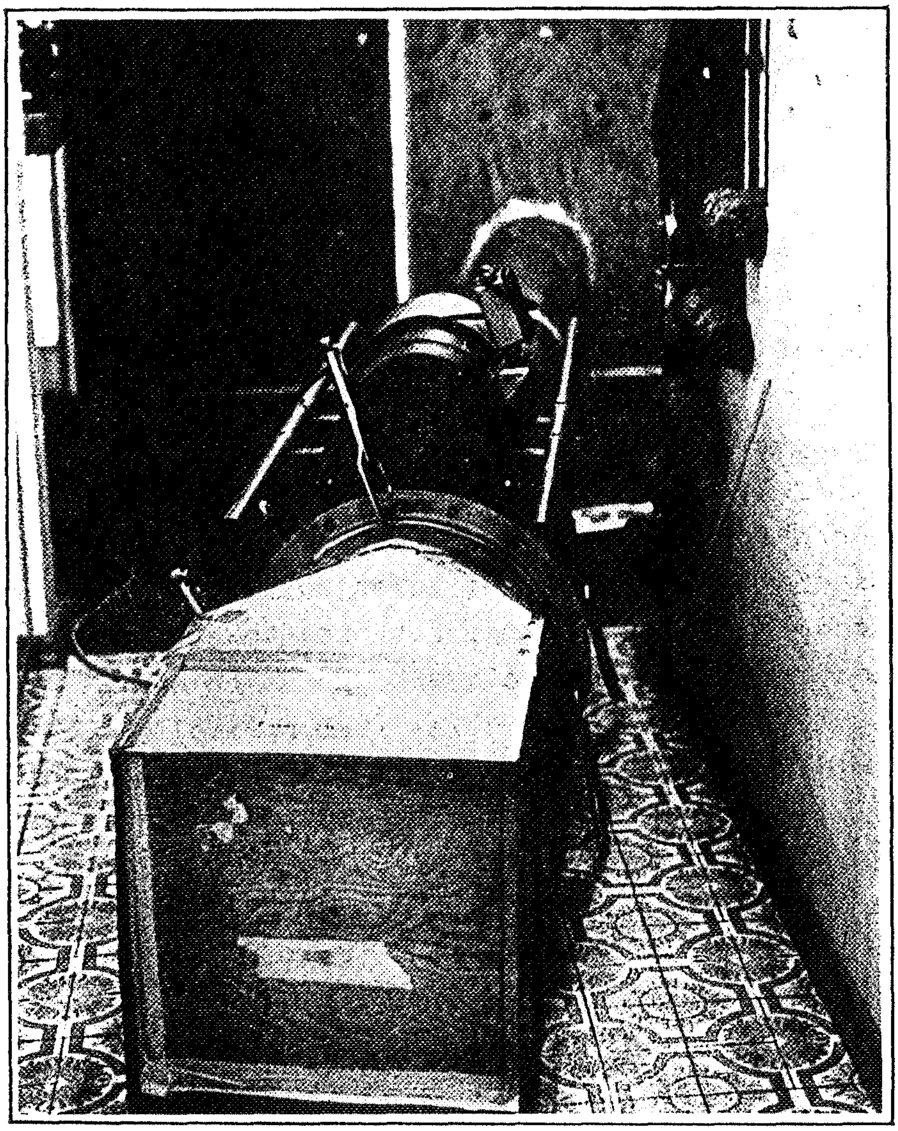


FIGURE 5A.
NRC AIR TEST
EQUIPMENT

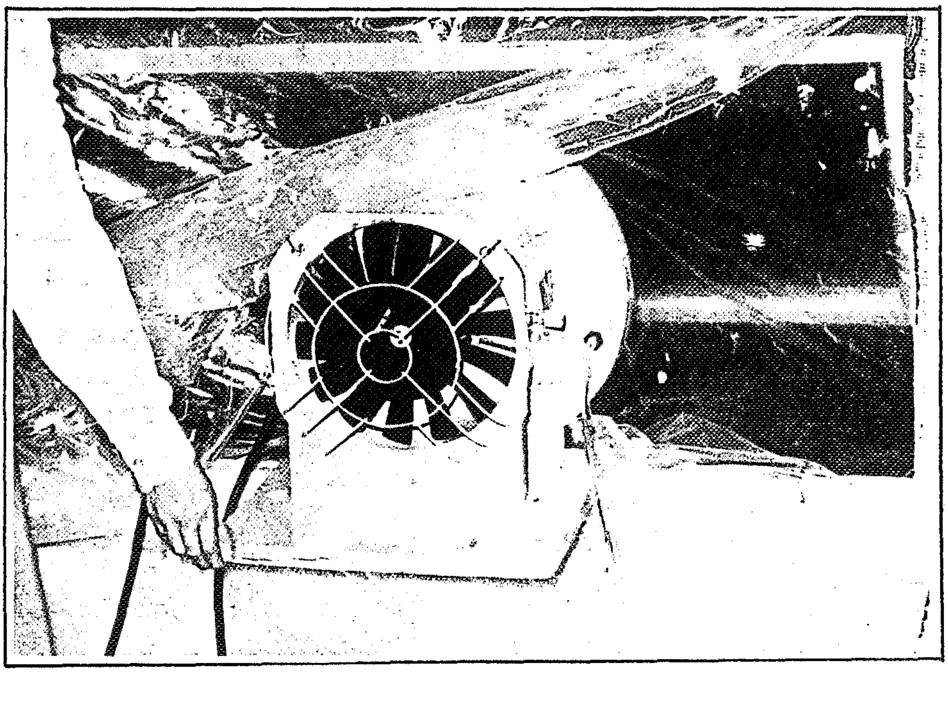


FIGURE 5B.
ONTARIO HYDRO
AIR TEST
EQUIPMENT

is used to control the rate of air exhaust, Q. In tests using this equipment, a series of ΔP values at corresponding Q values are measured. A plot of log Q versus log ΔP (a straight line) is called the characteristic air leakage curve of that particular test house.

Hovey & Associates, Ltd. of Ottawa conducted 8 air-leakage tests using the NRC equipment. Since these tests were included in an NRC study involving the air-leakage testing of the building envelope, care was taken to seal not only the furnace and water heater flues but also the fireplace, dryer vent, and exhaust fan openings.

The Ontario Hydro air test equipment consists of a portable fan of 1500 cfm capacity. The calibration curve relating the exhaust air flow, Q, to the pressure difference, ΔP, is known for this fan. An air test conducted with this fan determines one point, (ΔP, Q), where ΔP is measured, and a corresponding Q is obtained from the calibration graph. In these tests, only the furnace and water heater flues were sealed.

Although two different types of air test equipment were used in this study, they do the same thing and give results that can be used comparatively for all 34 houses. The single ΔP and Q of the Ontario Hydro test becomes one point on the NRC curve and can be used to calculate an equivalent leakage area.

Saul Stricker of Ontario Hydro has suggested a correlation between inferred air change and equivalent leakage area:

ELA (ft^2)	Inferred A/C cfm
0.75	30
1.50	60
2.00	90

The inferred air change must be divided by the building volume to obtain air change per hour.

When Stricker's correlation was applied to the test results in this study, remarkably low air change rates were obtained. Since no other method of estimating air change rates from air leakage data exists, these low values were used in the calculation of the theoretical heat loss coefficients (G). Consequently, the G's may all be slightly higher than derived here, but this would have no significant effect on the fuel/G findings.

The ΔP, Q, ELA and inferred ACPH for each test house are listed in Tables 10A and 10B.

House	ΔP ("H_2O)	Q (cfm)	ELA (ft^2)	ACPH
T1	.125	1550	1.82	.13
T2	.145	1547	1.69	.19
T3	.110	1553	1.95	.20
T4	.115	1552	1.90	.19
T5	.140	1548	1.72	.17
T6	.095	1557	2.10	.23
01	.20	1536	1.43	.26
02	.17	1542	1.55	.29
03	.20	1536	1.43	.26
04	.19	1538	1.47	.27
05	.48	1480	0.89	.11
06	.21	1534	1.39	.25
W1	.50	1476	0.87	.11
W2	.50	1476	0.87	.12
W3	.53	1469	0.84	.12
W4	.42	1493	0.96	.13
W5	.55	1465	0.82	.12
W6	.41	1495	0.97	.13

TABLE 10A. AIR LEAKAGE TEST DATA AND RESULTS: LESS HIGHLY INSULATED

House	ΔP ("H_2O)	Q (cfm)	ELA (ft^2)	ACPH
T1				
T2	0.22	1532	1.36	.15
T3	0.10	1556	2.05	.22
T4	0.085	1559	2.22	.26
T5	0.10	1556	2.05	.22
T6	0.08	1559	2.29	.28
01	0.21	1534	1.39	.26
02	0.17	1542	1.55	.29
03	0.20	1536	1.43	.26
04	0.15	1546	1.66	.31
05	0.17	1542	1.55	.18
06	0.23	1531	1.33	.24
W1	0.42	1493	0.96	.17
W2	0.42	1493	0.96	.13
W3				
W4	0.33	1511	1.09	.15
W5	0.375	1502	1.02	.14
W6	0.35	1507	1.06	.14

TABLE 10B. AIR LEAKAGE TEST DATA AND RESULTS : HIGHLY INSULATED

Appendix 4

SITE VISIT CHECKLIST

Project No. ________

Date ________________________ 19 ___ Building No.__________

Interviewer ______________________________

Home Owner ______________________________

City/Town ____________________________ Province ____________________

Photos Of Dwelling:

____

Doors:

	Front	Side	Rear
Single Door Set			
Double Door Set			
Wood - Hollow Core			
- Solid Core			
Metal Clad - Insulated			
Glazing - None			
- Single			
- Double			
Storm Door - None			
- Wood			
- Aluminum			
Weatherstripping			

Sliding Doors - Yes ☐ No ☐ No. of sets ____________

Type: Wood ☐ Vinyl Clad Wood ☐ Aluminum ☐

Comments: ____

____

____

Ambient (Outside) Conditions

Weather: Bright Sun ☐ Hazy Sun ☐ Cloudy Bright ☐ Cloudy Dull ☐

No.Precip. ☐ Rain ☐ Freezing Rain ☐ Snow ☐

Temperature: DB ___ WB ___ RH ___ Time ______ Measured Temp. _______

Wind: Speed ______ Direction ______ Constant _______ Gusting ______

Comments: ____

Interior Temperature

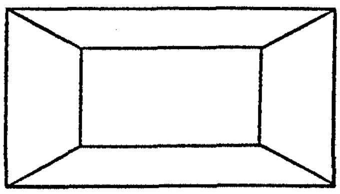
Location of Thermostat ___________

Thermostat setting ______ reading ______; Humidistat setting ______ reading ______

* Temperature Distribution

Location	LR	DR	KIT	WR	BRI	BR2	BR3	ATTIC	BMT	LDRY	FR	
DB (°F)												
WB (°F)												
RH (%)												
°F frm fl.												

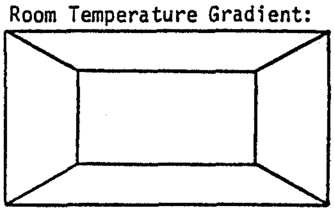
Room Temperature Gradient: Room ______________________



Location	Window	Ceil	Floor	Hot Air	
DB (°F)					
WB (°F)					
RH (%)					
Ref.Temp.					

Comments: ____

Room Temperature Gradient: Room ______________________



Location	Window	Ceil	Floor	Hot Air	
DB (°F)					
WB (°F)					
RH (%)					
Ref.Temp.					

Comments: ____

* NOTE: Ensure that uncarpeted rooms are noted and the temperatures are recorded on the Temperature Distribution table.

Site Plan Sketch - To depict dwelling floor plan, orientation, vegetation, exposure and thermograms (if taken)

Note - (#) indicates the number and location of photographs

[#] indicates the number and location of thermograms

Main Floor -

Orientation: ___________

Additional Floor -

Dwelling Exterior

Chimney: Type ______________________ Number __________

Condition ______________________

____

Roof: Buckling ☐ Waviness ☐

Comments ______________________

____

Soffit Condition: Peal ☐ Rot ☐

Slope - In line with roof ☐ flat ☐

Soffit Vents ☐

Comments ______________________

____

Exterior Siding: Type ______________________ Gen. Tightness __________

Caulking around doors and windows ______________________

____

Paint Condition (blistering, peeling, etc.) ______________________

____

Comments ______________________

____

Foundation: Type ______________________

Average Projection ______________________

Skirtboard, etc. Rot ☐ Water Marking ☐

Under-Skirt Edge ______________________

____

Comments ______________________

____

Dwelling Interior

Basement: Full ☐ Crawl ☐ Dirt Floor ☐ Concrete Floor ☐

Mould ☐ Efflorescence ☐ Damp ☐ Sump ☐

Finished - Floor ☐ Wall ☐ Ceiling ☐ % of Total [%]

Size ______________________

Insulation ______________________

Comments ______________________

____

Living Area:

Interior Finish

Type ______________________________

____

Condition ______________________________

Heated Perimeter ☐ Dust Marking ☐

Detailing At Corners ______________________________

Mouldings ______________________________

Comments ______________________________

____

Windows

Type ______________________________

Condition ______________________________

Tightness ______________________________

Condensation (Int. Panes) ☐ Frost Patterns (Ext. Panes) ☐

Comments ______________________________

____

Ceiling

Type ______________________________

Condition ______________________________

Stains - Water Leak ☐ Condensation Patterns ☐

Comments ______________________________

____

Attic

Type ______________________________

Size ______________________________

Attic Venting ______________________________

Power ☐ Eave - Continuous ☐ Ridge - Continuous ☐ Roof ☐

- Individual ☐ - Individual ☐

Roof Sheathing - Water Marking ☐ Rot ☐

Attic Insulation: Observed depth ______________________________

Uniformity ______________________________

Condition/Comments: ______________________________

Furnace Efficiency

Fuel: Oil No. 1 ☐ Gas Natural ☐ Electricity ☐

No. 2 ☐ MFG ☐ Other ☐ ____________

Propane ☐ ____________

Butane ☐ ____________

Features: Barometric Damper ☐ Draft Diverter (Hood) ☐

Stack Damper ☐ Integral Draft Diverter ☐

Pilot Light ☐ Atmospheric Burner ☐

Intermittent Ignition Device ☐ Power Burner ☐

Description: ____

____

____

Status Of Pilot Light During Non-Heating Season On ☐ Off ☐

Testing: Room Temp. T_{RA} ☐

Steady State (10 Min.)

	Flue	Stack
Temp	☐	☐
CO_2%	☐	☐

(Record stack data only when furnace is equipped with an integral draft diverter)

Steady State Efficiency ☐

Appendix 5

CALCULATION OF G, THE THEORETICAL HEAT LOSS COEFFICIENT (AND METHOD OF PREDICTING ANNUAL HEATING DEMAND)

Scanada

ESTIMATION OF G, THE THEORETICAL HEAT LOSS COEFFICIENT OF A RESIDENTIAL BUILDING

Bldg. No. ________

Project No.: ______________ Date: ________

Home Owner ________________

Telephone No. ________________

Street ________________

City/Town ________________

Province ________ Postal Code ________

Age ________ # of Storeys ________

Builder ________________

Degree Day Area ________________

Adjusted Degree Day From Graph ________

WALL SECTION:

Net Wall Area (Ft^2) ________________

Group ________

Insulation - Type ________________

- Thickness ________________

Wall R-Value ________________

$\frac{\text{Net Wall Area}}{\text{Total R-Value}}$ = ________ $\frac{\text{BTU}}{{}^\circ\text{F Hr}}$ A

CEILING/ATTIC/ROOF SECTION:

	Ceiling(C)	Attic (A)	Roof (RF)
Attic Area (Ft^2)			
Group			
Insulation - Type			
-Thickness			
Roof R-Value			

$\frac{Area_C}{R_C} + \frac{Area_A}{R_A} + \frac{Area_{RF}}{R_{RF}}$ = ________ $\frac{\text{BTU}}{{}^\circ\text{F Hr}}$ B

Approx. Roof Slope ________

Attic: Accessible ☐ Inaccessible ☐

Note: use misc. section to calculate heat losses for kneewalls

WINDOWS:

Single Glazing - Area (Ft^2) ________ R.1.1

Double Glazing - Area (Ft^2) ________ R.1.8

Triple Glazing - Area (Ft^2) ________ R.2.8

Area/R =

Area/R =

Area/R = ________ $\frac{\text{BTU}}{{}^\circ\text{F Hr}}$

TOTAL ________ C

BASEMENT:

Basement or Foundation Perimeter ________ ft.

Perimeter x Heat Loss Factor ________ =

Exposure (area) above ground level ________ sq.ft.

÷ R________ =

Area of glazed sections in basement wall ________ sq.ft

÷ R________ =

If Applicable:

Wood header joist and sill=perimeter x 9/12 sq.ft.

÷ R________ =

Total ________ $\frac{\text{BTU}}{{}^\circ\text{F Hr.}}$ D

Bldg. No.__________

NOTE: The following may not be applicable for the given house. If applicable, include in the calculation of heat loss and demand in the same manner as A,B,C & D.

DOORS:

Door Area ____________________

Type ____________________

Door R-Value ____________________

$$\frac{\text{Door Area}}{\text{R-Value}} = \_\_\_\_\_\_ \frac{\text{BTU}}{^{\circ}\text{F Hr}} \quad \text{E}$$

FLOOR SECTION:

Floor Area Above An Unheated Space (ft^2) ________

Group ________

Insulation - Type ____________________

- Thickness ____________________

Floor R-Value ____________________

$$\frac{\text{Floor Area}}{\text{R-Value}} = \_\_\_\_\_\_ \frac{\text{BTU}}{^{\circ}\text{F Hr}} \quad \text{F}$$

MISC. SECTION: DEFINE SECTION ... ____________________

Area (ft^2) ____________________

Group ________

Insulation - Type ____________________

- Thickness ____________________

R-Value ____________________

$$\frac{\text{Area}}{\text{R-Value}} = \_\_\_\_\_\_ \frac{\text{BTU}}{^{\circ}\text{F Hr}} \quad \text{M}$$

Remaining Factors To Be Included:

BUILDING VOLUME: Total Volume (ft^3) [ ] V

AIR CHANGE:

Estimated Number of Air Changes/Hour [ ] ac

Heat Loss Factor G = (A + B + C + D + E + F + M + V x ac x .018)

$$= \_\_\_\_\_\_\_\_\_\_ \frac{\text{BTU}}{^{\circ}\text{F Hr}}$$

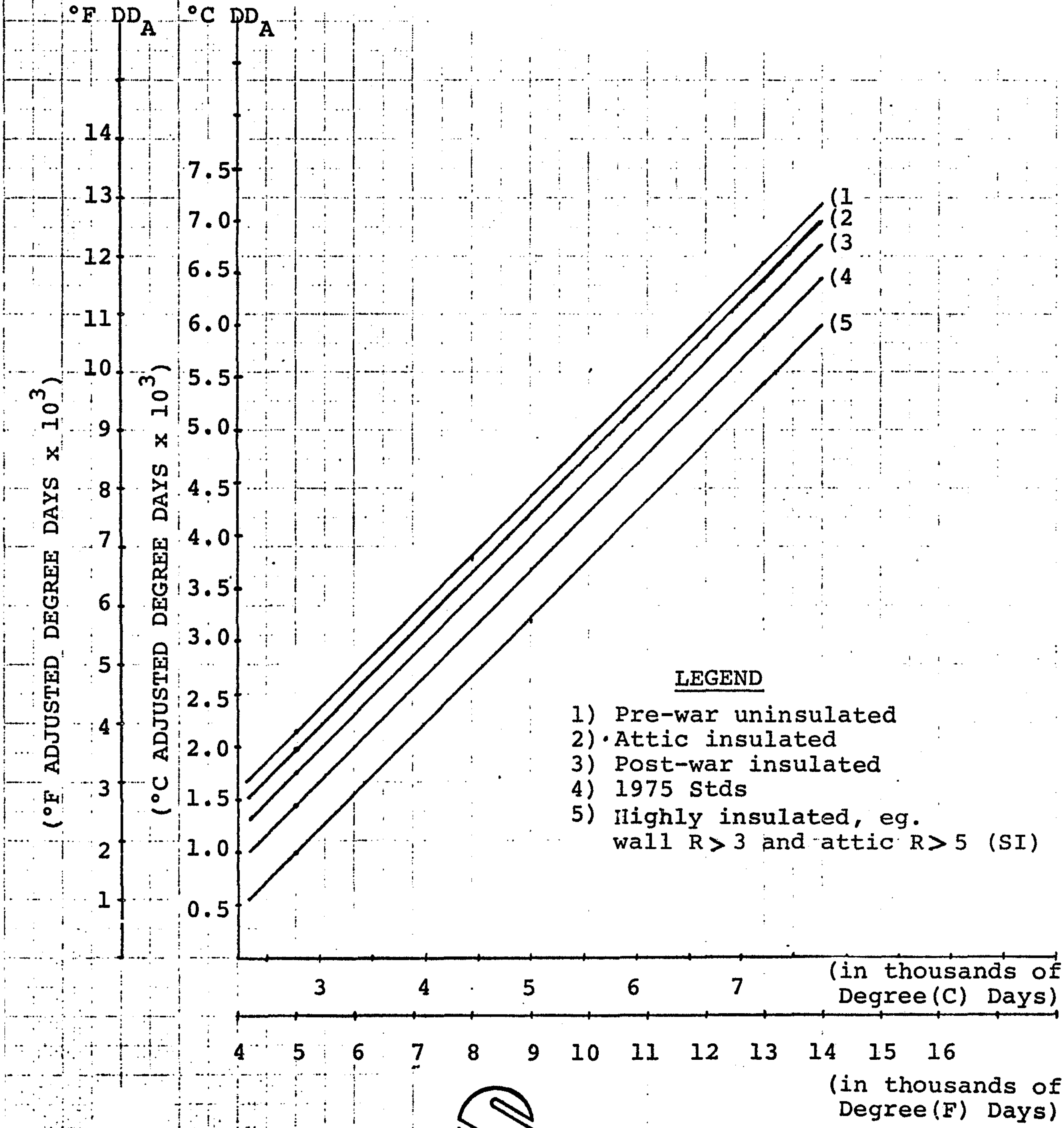
Annual Heating Demand

The simplified "normal" form of the Scanada method of predicting winter heating demand is:

Heating Demand = G x 24 x adjusted degree days

where adjusted degree days are taken from the graph, overleaf

ADJUSTED DEGREE DAYS AS A FUNCTION OF ENVELOPE CLASS & DEGREE DAYS



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Appendix 6

DETERMINATION OF FUEL REQUIRED FOR WATER HEATING IN GAS HEATED HOUSES

For the gas-heated houses with gas water heaters, it was necessary to calculate (and subtract from the total fuel consumption) that quantity of fuel used to heat water. Two methods were used and the results averaged.

First, the gas consumptions for June, July and August were averaged to obtain monthly water heating fuel requirements.

Next, estimates of Average per Capita Hot Water Use from and Ontario Hydro report, Energy Usage and Relative Utilization Efficiencies of Electric, Gas and Oil Heated Single Family Homes, were used to typify the gas used for water heating. Ontario Hydro assumed that water is heated through 100°F with a service efficiency of 65%. Using their figures, the following estimates of gas required to heat water were obtained:

No. of People	Gas Required for Water Heating (ccf per month)
2	14
3	17
4	21
5	24
6	27
7	29

For each household, the results from both methods were averaged to obtain a final estimate of the gas required for water heating. Hopefully, this averaging "normalizes" and helps remove the effect of any peculiar summer circumstances (such as vacation, or extra showering).

An example of the above calculations is presented as follows:

House: Winnipeg (HI) #2

No. of People: 4

		Summer Gas Consumption (ccf)
Method 1:		
	June 1978	38
	July 1978	28
	August 1978	25
	Average:	30 ccf/month

Method 2: From Ont. Hydro formula: Gas Required to Heat Water: 4 People: 21 ccf/month

Final Estimate: Gas Required for Water Heating

$$= \frac{(30 + 21)}{2}$$

$$= 25.5 \text{ ccf/month}$$

OTHER PUBLICATIONS OF THE HUDAC TECHNICAL RESEARCH COMMITTEE

HUDAC EXPERIMENTAL PROJECTS MARK I-IV
— Hespeler, Dartmouth, Calgary & Ottawa, 1957-63

This report provides a historical record of these early houses and their experimental features. The material was collected and edited from all the known sources of information which appeared when they were built and includes comments on the subsequent performance of the innovative features up to 1973.

HUDAC EXPERIMENTAL PROJECT MARK VI
— Kitchener, 1969

This experimental house incorporated many new building materials and building practices which were believed to have considerable merit. The use of precast concrete for the foundations and steel floor joists were among the interesting innovations tried out. This report describes all of the features in detail.

PLUMBING VENTING IN EXPERIMENTAL HOUSES MARK IV & VI, 1963-69

Studies were undertaken to investigate the possibility of reducing the diameter of plumbing pipe used for back venting household plumbing fixtures. This report indicates that most plumbing codes demand excessively large pipe and roof vents.

HAMILTON EXPERIMENTAL HOUSE 1970

Based on the Mark VI plan, this experimental house was built as part of an on-going program to refine some of the innovative techniques pioneered in the Mark VI house. This report describes the materials and methods of construction as well as cost figures relating to the experimental features.

HUDAC EXPERIMENTAL PROJECT MARK VII
— Vancouver, 1972

This experimental project tried out several new construction methods designed to overcome problems faced in housing built on the West Coast. It included an experimental precast concrete foundation, exterior walls built on the "Rain Screen Principle", reduced diameter plumbing venting, etc.

HUDAC EXPERIMENTAL PROJECT MARK VIII
— Winnipeg, 1972

This report contains the technical aspects of the Mark VIII. (see also Report RS. 702 which contains the social aspects)

HUDAC EXPERIMENTAL PROJECT MARK IX
— Regina, 1972

The Mark IX incorporated several new and unique construction methods among which was a steel foundation system designed to overcome the problem of building on swelling prairie clays. Steel floor joists, wall studs and other members were also utilized to ascertain their competitive position with traditional materials.

HUDAC EXPERIMENTAL PROJECT MARK X
— Guelph, 1973

The Mark X was another in a planned series of houses to further develop the steel concept as a viable building material. It was the second house built with an all steel foundation system. A steel floor system, steel bearing and non-bearing studs and other steel products were incorporated.

COST STUDY OF A TWO STOREY WOOD FRAME HOUSE, 1973

This study resulted in a new bench mark against which it is now possible to compare new forms of residential low-rise construction. It provided the means for evaluating innovative building systems and techniques and judging their merits against those of conventional construction.

MANUAL OF PROCEDURE FOR COMPARATIVE TIME AND MATERIAL STUDIES FOR NEW HOUSING, 1973

This text book describes the methods to use for conducting time and material studies of new housing. By utilizing the methods and forms contained in this book it will be possible to compare the results of such studies with other construction systems used previously or elsewhere, on an equal basis.

PRECAST CONCRETE FOUNDATION SYSTEMS FOR LOW-RISE HOUSING, 1973

Commencing with the Mark VI Experimental Project, HUDAC has been in the process of developing an economical and practical system for building precast concrete basements for low-rise dwellings. This report outlines the progress to date in this form of development.

DESIGN CRITERIA FOR BASEMENT FOUNDATION SYSTEMS IN CANADIAN HOUSING, 1975

The National Building Code and the Residential Standards do not specifically set forth the criteria which the Code requires for basement foundation design. This report establishes these criteria to assist those designing new systems.

A GUIDE TO THE CONSTRUCTION OF CAST-IN-PLACE CONCRETE BASEMENTS FOR HOUSING AND SMALL BUILDINGS (Metric version 1978)

This Guide provides builders with information which will be helpful in preventing foundation failures in cast-in-place concrete basements. By conforming to good practice and workmanship many of the complaints and the necessity for callbacks can be eliminated.

ZERO INCREASE IN STORM WATER RUNOFF,1976

This study outlines the principles of some new, emerging methods of storm water drainage. It investigates whether the new methods can be incorporated in housing developments without increasing the cost of housing.

DESIGN GUIDELINES FOR RESIDENTIAL STREETS, 1977

This report establishes objectives, principles and design considerations for residential streets in new developments in order to stimulate all concerned to re-evaluate current practices which may not meet present day objectives.

UPDATE ON SANITARY DRAINAGE AND SEWAGE DISPOSAL METHODS, 1978

This report indicates economies which could be realized if up to date design principles for sanitary drainage and disposal systems were followed by municipalities in subdivision requirements as well as designs for their own treatment systems and connections.